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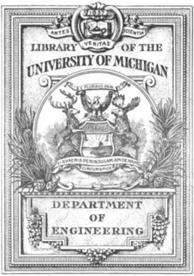
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Tidskrift for Söveaen......Horten, Norway.

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THE SUPERHEATING OF STEAM.

A Communication made to "The Industrial Society of the North of France," by AIMÉ WITZ, Engineer of Arts and Manufactures, and Professor in the Free Faculty of the Sciences at Lille.

Translated from "L'Energie" of June 20th, 1903,

BY BENJAMIN F. ISHERWOOD, CHIEF ENGINEER UNITED STATES NAVY, MEMBER.

HISTORICAL.

The steam engine left the hands of Watt complete in all its mechanical parts; that great intelligence also enriched science by sane observations on the nature and properties of steam, showing himself to have been a consummate scientist as well as an ingenious mechanician; he invented the fly-wheel, the crank, the centrifugal governor, the parallel motion, and all which constitutes the steam engine; he invented the separate condenser and the expansive use of steam. In advance of the admirable discoveries of Hirn, and with the intuition of genius, he comprehended the interaction of the heat of the steam with the metal of the cylinder, and, in

order to prevent it, he invented steam jacketing the cylinder; he also suggested to Hornblower the expansion of steam in compounded cylinders; one thing only appears to have escaped him, namely, superheating the steam after its generation in order to at least greatly lessen, if not to absolutely prevent, the interaction above referred to.

There is much difficulty in determining to whom belongs the glory of this important invention.

Mr. Raffard* has exhumed from the Repertory of French Patents in the "Conservatoire des Arts et Metiers," the specification of a Mr. Becker, mechanician of Strasbourg, dated the 20th November, 1827, relative to a high-pressure engine in which the steam before entering the cylinder is raised to a very high temperature above its temperature in the boiler. The patent mentions a superheating to 410 Fahrenheit degrees.

Alsace is thus truly the cradle of superheating, and the obscure name of Becker passes to posterity with those of the masters of the Alsatian school who will be mentioned later.

Bryan Donkin† gives the honor of the invention to J. Howard of Bermondsey, who, in 1832, realized a notable economy by means of superheating apparatus. Dr. Haycroft, of Greenwich, commenced in 1835, and with equal success, the practice of superheating; but no authentic documents exist describing the apparatus adopted by these inventors.

Superheating belongs also to the North, for Raffard found a patent issued to Quillacq, dated the 3d July, 1849, for the use of steam "non-saturated and superheated"; the apparatus was applied to a Cornish boiler having an internal furnace with which it communicated by means of equilibrium valves; a supplement to the patent, added in the same year, shows a superheater (Quillacq named it a reheater of steam) of annular form placed in the current of the hot gases of combustion, with a provision for putting it out of use in case of need, and which was also a regulator of the superheating. A Mr.

*"Bulletin Technologique," September, 1892.

†"Engineering," 7th April, 1893: "On the use of superheated steam in steam engines."

Moncheuil, in 1850, obtained a second certificate of addition to Quillacq's patent, the addition being for a tubular superheater "composed of a group of small tubes piaced within a large tube through which passed the flame or hot gases from the furnace."

Raffard believes that he can include himself among the early promotors of superheating, and cites his patent of 1851 in evidence; this patent relates to a superheater for drying expanded steam, and was placed in the steam room of the boiler itself, but there must be distinctly understood that this apparatus, otherwise very interesting, was only a dryer, and that it could not in any manner produce superheating, that is to say, increase of temperature above the temperature normal to the saturated steam of the boiler, since it was immersed in that very steam.*

Mr. E. Bède, at that time a Professor in the University of Liège, made, in 1854, experiments on superheating in the spinning factory of Saint Léonard, and the only reproach that can be made against them is that they were too timidly made. The distinguished Professor employed a copper tube of U form, which he placed in the smoke conduits for the purpose principally of vaporizing the entrained water and of drying the steam. He took out a Belgian patent, dated the 27th of September, 1854.

Marc Seguin, of Lyon, in 1855 experimented with a superheater formed of iron tubes immersed in a mass of cast iron for the purpose of protecting them against occasional very high temperatures; they were heated to redness. Mr. Lencauchez, who described these experiments, informs us that the Farcot steam engine, to which the apparatus was attached, adapted itself very badly to the too high temperature of the steam used in it.

* Raffard's method was to reduce the pressure and consequently the temperature of the boiler steam by expansion as it passed through his superheater. And as the steam after its expansion is subjected to the temperature of the same steam before its expansion, the expanded steam will become superheated by the difference of the two temperatures. The vaporization of entrained water, and the drying of the steam, and the superheating of the steam, are all caused simultaneously by the expansion of the steam. The temperatures of the steam before its expansion and after its expansion are the temperatures normal to the pressures before and after the expansion.—TRANSLATOR.

But to the immortal Hirn, the great thermodynamist, the scientific glory of Alsace, belongs with just title the invention of rational superheating. His patent of the 12th November, 1855, describes a *hyper-thermo generator* formed of a group of tubes placed in the flue in the middle of the gases of combustion hot enough to impart to the steam a high degree of superheating.

These tubes were of cast iron, which metal was chosen "because of its unalterability," said the patent; the joints were metallic and were formed of a copper ring with sharp edges strongly compressed between the flanges by screws; the group of tubes was placed in the flue at the foot of the chimney. In all cases there were valves which permitted the whole or a part of the hot gases to act upon the group of tubes, and thus to regulate at will the degree of the superheating.

Hirn's patent is a very important document in the history of superheating. It is mentioned with so much the greater emphasis as this great originator, this fecund inventor, this ingenious mechanician, took out only three patents during his long and brilliant career.

Hirn's first experiments on the effects of superheating commenced in 1856, and were made on the celebrated steam engines at Logelbach, since become classical owing to the importance of the researches of which they were the subject. The first was a beam engine of one cylinder without steam-jackets and with four valves; the steam valves were operated by a differential movement which enabled them to be closed at any point in the stroke of the piston, so as to produce any measure of expansion desired for the steam. The steam was supplied in a more or less superheated state, and Hirn valued at 20 per centum the economy produced by a temperature of 410 Fahrenheit degrees; and at 47 per centum the economy produced by a temperature of 473 Fahrenheit degrees. Then he experimented on a compound or Woolf steam engine with steam-jacketed cylinders. The economy produced by the superheating was again clearly shown, and was valued at

from 12 to 15 per centum. He now resolved to separately ascertain the economy produced by the steam jacketing alone, and by the superheating alone by not admitting steam into the jackets. The superheating was then more economical by 8 to 10 per centum "comparatively with what was obtained with saturated steam and steam jacketing."* The superheating was consequently more economical than the steam jacketing.

Hirn recounts how he was deceived in the application of superheating to a compound steam engine without steam jacketing, in the environs of Colmar. An economy of from 25 to 30 per centum was expected, an economic loss of 4 per centum was obtained. This check was later explained and attributed to the special design of the single steam valve which was used for performing the multiple function of operating both cylinders, but which produced a saturation of the superheated steam, thus sending as a net result only a more considerable loss to the condenser. The lesson was not lost on Hirn, who deduced from it important considerations for the rational employment of saturated steam.

He praised a superheating of 446 Fahrenheit degrees. This condition of moderate superheating realized what was a very satisfactory functioning to him; and in 1876 he was able to say that certain steam engines had worked under it during 20 years without any wear or any deterioration whatever.† The Alsatian school does not appear to have exaggerated the thesis of its master, and Hallauer fixed at 482 Fahrenheit degrees a limit that it was not advisable to pass. The important experiments made with such éclat by Hirn, Leloutre, Hallauer, etc., clearly established the end to be attained, namely, the prevention by superheating of the cooling produced in the cylinder during the expansion and the exhaust; and of restricting, if not entirely annulling, the liquefactions which take place during the admission. They have shown that the water of this liquefaction is the enemy, and

*"Analytical and Experimental Exposition of the Mechanical Theory of Heat," by G. A. Hirn, Volume II, page 84. 2d edition. Paris. 1876.

† Hirn, "Analytical Exposition, etc.," Volume II, page 122.

that in the last analysis it is necessary to have the metal again dry at the end of the stroke of the piston, so as to lose nothing to the condenser.

This result can be obtained in a certain measure by the addition of steam jackets to the cylinder, but much more surely by superheating the steam. Nevertheless, there must be acknowledged that though the steam jackets are less economical, their application is easier, they do not cause any injuries, nor require any precautions, nor any special knowledge; while, on the contrary, the superheaters are exposed to deterioration and to destruction by overheating; the industrials who use them have on their hands the case of an apparatus always delicate and sometimes dangerous, and when an accident occurs they have no recourse against the contractors, who naturally endeavor to avoid the responsibility, and to excuse themselves on the ground of incompetent management. On the other hand, an excess of superheating carbonizes the lubricating oil, causes valves and pistons to grip, and destroys the packings of the stuffing boxes; hence, steam jackets should be preferred to superheaters. The same considerations militate in favor of multiple-expansion cylinders, which should thus supersede superheating. This, in fact, is what happens, and the builders of steam engines make their efforts in that direction.

The same evolution has taken place in England.

John Penn introduced superheating in the steamers of the Peninsular and Oriental Steamship Company in 1859, with great success; long-continued experiments made in the Woolwich Arsenal showed an economy of coal of 30 per centum. Parson, Partridge, Pilgrim, Siemens, also established superheaters which were often merely dryers, and always gave only a slight superheating. On board the *Ceylon* the temperature of the superheated steam was 131 degrees Fahrenheit above the saturation temperature, which produced an economy of 25 per centum. On board the *Nepaul*, over 50 per centum of economy was obtained. With single-cylinder engines, supplied with slightly superheated steam at a press-

ure of about 35 pounds per square inch above the atmosphere, the consumption of coal was from 2.42 to 2.65 pounds per indicated horsepower. These results were considered as very encouraging at that time; but equally as good were obtained from compound engines supplied with steam of 70 pounds per square inch above the atmosphere. Now, with equal economy, the superheating is sure to go out of use for the reasons above stated.*

Ghislain in Belgium, Wethered in America, and others in Germany and elsewhere, installed superheaters with as much economy but with no more perseverance than in Alsace. They tried the process, and after a short time abandoned it. Messrs. Dollfus, Mieg & Company, at Mulhouse, placed in their establishment an engine of 200 horsepower with superheater; they soon removed the superheater, although they declared it increased the power of the engine. La Compagnie des Messageries, et la Compagnie Transatlantique established superheaters on board of their vessels, but they never renewed them. The battleship *Fontenoy*, of the French Navy, had a superheater installed which was the subject of a eulogistic report by the Minister of Marine in 1862, but this did not save it.

What was the complaint against it?

The subjection to it, or constraint which it entailed upon the use of the engines, the breakages in them that it caused, the gripments in them to which it exposed them, all as before stated. The pretence was made that horizontal cylinders were nowise proper for the use of superheated steam because their ovalization, considered at that time as inevitable, caused a greater leakage of superheated than of saturated steam.

Briefly, while the principle of superheating was accepted, its practical application was ignored. Also, the technical works posterior to 1862 did not even mention it. The "Aide-Memoire" of Claudel, of 1867, that mine of useful information, omits superheating, the word itself not being found in

* Interesting experiments were made by Isherwood, Loring and Emery; a résumé of them is given by Thurston in his "Treatise on the Steam Engine."

the Table of Contents. The "Théorie des Machines à Vapeur," by E. Bède, of 1863, is mute on this subject. The "Théorie des Moteurs à Vapeur," published in 1872 by Professor Dwelshauvers-Dery in "La Revue Universelle des Mines," spoke with much science of liquefaction, of high pressure, of great measures of expansion, of waste space, and of steam jacketing, but neglected the effects of superheating. Mr. Pochet in his "Nouvelle Méchanique Industrielle," 1873, only mentions superheating to discountenance it. Resal, in his "Traité de Mechanique Généralle," 1876, says superheating has been renounced because it entrains more disadvantages than advantages.

It is then not at all astonishing that at the Vienna Exposition, of 1873, no prize had to be given to any superheater; Mr. Charles Meunier-Dollfus, in his admirable Report presented to the Industrial Society of Mulhouse (29th October, 1873), did not even refer to this lacune of the Exposition, which proves that he was not astonished, and that he did not regret it; superheating was no longer the order of the day. Mr. Lencauchez summed up the situation in a scientific communication made to the civil engineers of France, the 20th of August, 1890, by saying that "if the employment of dry steam was to be investigated, that of superheated steam ought to be set aside as completely unrealizable in industrial practice, *at least for the present*.*

This reserve of the perspicuous engineer should be maintained; in fact, before superheating can become practical a metal must be found capable of resisting high temperatures, capable of replacing the hemp packing of stuffing boxes with incombustible material; lubricants which will not turn into cart grease, but which will retain their lubricating quality under high temperature.

Now this progress has been realized rapidly enough.

Since 1888 has been manifested a return, timid though it be, yet undeniable, towards superheating, which has been too much disparaged.

*"Memoirs of The Society of Civil Engineers of France," 1890; "Advantages of High Pressure Steam in Compound Engines," by A. Lencauchez.

In 1889 was seen at the Exposition Messrs. Lagosse and Bouché's drying reheater of steam. It was a battery of U-shaped tubes placed in the bottom of the chimney and traversed by the steam current. Mr. Uhler also exhibited a dryer—the name of superheater was carefully avoided—and Mr. Olry, in his important report took the precaution to say that "the dryers which were so often added to multitubular boilers are never subjected to a high temperature, and ought not, consequently, to be considered as superheaters.*

But the makers of superheaters soon became bolder, and Mr. Uhler commenced constructing them as such in 1890. He adopted the Field tube suspended in the current of hot gases, and, at first, inserted in a cast-iron box, and afterwards in a plate-iron box.

From this moment a revolution took place in the ideas on this subject, and an energetic movement was made to realize superheating. Gehre, in Germany, used tubes secured in plate iron and having a very large aggregate surface. This superheater was placed in the base of the chimney. Schwoerer, who had been Hirn's distinguished secretary, and had received his latest ideas on this subject, returned to the winged tubes, which he made of Niederbronn cast iron, and united by the Hirn joint. This appeared to him to have had the greatest success, as he recently stated that he had 4,800 superheaters in use in all countries.

At the Paris Exposition in 1900, and since, have appeared superheaters made by Steinmuller de Gummersbach, and by Petry-Dereux de Liège and Hering, all formed of U-shaped tubes, of straight tubes, or of tubes curved into coils. With unwelded tubes drawn from thin metal of the first quality, all the joints being out of the fire and otherwise so conditioned as not to be in danger of injury from it; with free dilatation and a good circulation of steam through the tubes; efficient and durable apparatus are made; the problem is not far from being solved, and superheating can be employed without injury. There remains one difficulty, that of moderating the

* Revue technique de l'Exhibition de 1889. 6^e partie t 1, p. 500.

superheating at will; of protecting the group of superheating tubes from the action of the heat between the time the fire is lighted and the time the engine is set in motion; or during the stoppings of the engine when there is no steam passing through the superheater; the most rational method consists in putting it out of circuit by means of valves operated by hand, which allow the current of hot gases to be deflected into an appropriate channel around the superheater, instead of allowing them to pass through it. When the arrangement of the boiler does not permit this means to be employed, recourse can be had to filling the superheater with water, but this exposes it to the formation of scale, the results of which would be disastrous. To moderate the superheating and to limit it to any degree wished, the superheated steam can be mixed, by means of suitable valves, with saturated steam drawn directly from the boiler for that purpose; this is a good process.

In the multitubular boiler the superheater is differently formed; it is a prolongation of the tubes that the steam current traverses on its way to the steam drum. Roser forms it at the side of the furnace; Niclausse places it in the middle of the steam-generating tubes; Belleville put it above them; Babcock & Wilcox, de Naeyer, etc., locate it on the empty angle between the tubes and the water and steam drum. Long discussions could be made as to the relative advantages of these arrangements.

The degree of the superheating evidently depends on the extent of the surfaces which produce it. There is generally given from 10 to 30 per centum of the steam-generating surface, and the endeavor is made to restrict the temperature to about 572 degrees Fahrenheit. Schmidt d'Aschersleben (Saxony) in 1892 desired to give a more intense superheating, and by employing a superheating surface five times as great as that of the steam-generating surface the temperature of the superheated steam rose to 716 degrees Fahrenheit and higher. Notwithstanding the very ingenious precautions taken to protect the first part of the superheating surface by supplying it with very wet steam, the coils of the Schmidt

boiler were so greatly injured by the high temperature that they did not last long. Mr. Serpollet found that he had very exceptional conditions in the case of his superheating tubes, but neither Schmidt nor he appears to have persevered in their designs, and today, like all others, they content themselves with moderate superheating.

This principle of moderation in superheating seems now to prevail, and the proof is seen in the Exposition at Dusseldorf, an Exposition that has made an era in superheating: there, as in Paris in 1900, the firm of Worthington used independent superheating. At Dusseldorf a great number of superheaters were in active use, namely, Hering's, Reichling's, Schwoerer's, Heizmann's, Koch's, etc.. This last apparatus was adapted to a boiler with an interior furnace, and was formed of a vertical assemblage of tubes suspended by a chain in the flue, so that the superheating surface could be varied and, consequently, the superheating temperature. The firm of Dingler exhibited an independent superheater, which apparatus, although giving evidently a less economy, had the great advantage of separate regulation from the draft of the boiler; it could also receive the steam from a battery of boilers, and in that case it is to be recommended, but the preference will always be given for the utilization of the waste heat from boilers by placing the superheating apparatus in the flue.

Under these conditions even a moderate superheating gives remarkable results, for the best steam engines, provided with all the improvements accumulated by theory and practice, during the last forty years, have their economy increased by it to an appreciable degree, which will be demonstrated in the second part of this article, and the why and how given.

II. THEORY OF SUPERHEATING.

Theory has sometimes preceded practice, but oftener the practicians propose the problems which the theoricians solve. The steam-engine had functioned for a long time before Sadi

Carnot discovered that heat was converted by this motor into work; and yet he failed to attain the complete explanation given by Seguin and by Meyer of the exact method by which units of heat are transformed into foot-pounds.

Likewise, before Hirn took out his patent of 1856 thermodynamists had unconsciously heated steam out of contact with its generating water, but the practicians would never have obtained any advantage from these first attempts if the scientists had not traced out the road, showed them how to follow it and warned them against false paths.

Hirn did not restrict himself to empty formulas; he sowed ideas with a full hand, but the seed unequally germinated; steam jacketing and multiple expansion ripened faster; now, however, the day of superheating has arrived, and the harvest promises to be abundant.

What should first be done in commencing an inquiry into the facts that have been already acquired? The endeavor should be made to demonstrate that the theory explains them and could have discovered them. For that purpose this work is a timid and modest contribution to the theory of superheating.

For the appreciation of the service resulting rendered by superheating, the assurance must first be had that it really does increase the economic performance of steam engines. With that object there can be compared the results in the following table, No. 1, of a number of experiments which have been made on different engines with and without it.

The economic gain by superheating appears evident from the above comparative table in which are included many types of steam engines and the most varied models with flat valves, Corliss valves, Sulzer valves, and the piston valves of Van den Kerchore; the column of Fahrenheit units of heat consumed per hour per indicated horsepower witness to a real progress accomplished by even moderate superheating. There can be guaranteed without risk of injury to the metal by overheating, a consumption of 5,400 to 7,200 Fahrenheit units of heat per indicated horsepower per hour, according to the

Table No. 1.—ECONOMIC EFFICIENCY OF THE BEST STEAM ENGINES.

Types of steam engine.	Condensation	Experimenters.	Date of experiment.	Diameters of the cylinders, in inches.	Stroke of the pistons, in feet.	Number of double strokes made by the piston per minute.	Pressure of steam, in pounds per sq. in., above atmosphere.	Indicated horsepower developed by engine.	Steam superheated, in Fahr. degrees.	Temperature, in degrees Fahr., of the steam as used.	Consumption per hour per indicated horsepower: Weight of steam, in pounds.	Consumption per hour per indicated horsepower: Units of heat, F.
				WITH DRY SATURATED STEAM.								
Single-cylinder	Without	Delafond	1884	19.6850	3.6089	62.7	103 54	236.712	0.0	339.93	21.2084	25,145.25
	With	Delafond	1884	19.6850	3.2803	59.9	103.83	154.849	0.0	340.12	16.2701	19,291.54
	Without	Official committee	1896	19.6850	3.2803	75 0	96.72	124.205	0.0	335.50	21.8919	25,926.20
	With	Vinçotte	1894	25.9842	5.0033	47.87	90.46	300.851	0.0	331.24	12.0372	14,239.18
Compound	With	Vinçotte	1891	31.4960—49.3700	5.9055	51.71	96.72	524.248	0.0	335.50	13.2057	15,639.29
	With	Witz	1892	25.9842—45.2755	4.4291	61.39	89.32	552.577	0.0	330.44	13.3754	15,819.13
	With	Witz	1897	32.0078—55.9841	5.5118	60.905	101.55	779.488	0.0	338.66	12.9411	15,338.43
Triple-expansion	With	Walther-Meunier	1891	20.6692—31.4960—43.3070	4.4291	64.47	82.49	273.304	0.0	325.52	12.5002	14,765.70
	With	Schroter	1890	19 7342—29.5866—47.3464	4.5981	66.41	147.21	707.868	0.0	364.35	12.4120	14,809.77
				WITH SUPERHEATED STEAM.								
Single-cylinder	With	Walther-Meunier	1892	28.0314	4.4849	60.15	64.86	304.638	118.8	430.22	16.2260	19,929.15
Compound	Without	Schroter	1894	12.2047—27.1653	1.6404	117.3	169.25	75.324	289.8	664.56	10.0310	13,744.17
	Without	Witz	1895	3.1496— 5.5118	0.2953	309.7	159.12	6.677	302.4	672.49	12.8970	17,750.18
	With	Gyssling	1893	26.6299—41.3660	4.4291	66.0	92.45	580.507	129.6	462.20	11.1399	14,049.52
	With	Witz	1902	11.8110—19.6850	1.9685	125.3	184.90	147.245	219.6	601.16	12.4120	16,508.94
	With	Walther-Meunier	1898	20.6692—32.4802	3.9370	...	119.47	323.585	305.1	654.65	9.7003	13,304.87
	With	Schroter	1902	12.7952—22.0472	2.7887	127.0	146.21	212.242	310.9	674.75	8.8626	12,226.15
Triple-expansion	With	Walther-Meunier	1897	22.0472—31.4960—45.2755	4.4947	69.98	162.14	804.890	179.1	550.61	10.2956	14,149.94
	With	Walther-Meunier	1901	19.2913—29.9212—49.2125	4.4291	67.11	157.73	830.228	86.0	455.44	11.0892	13,820.31

power developed by the engines, when superheating is employed. With saturated steam there has certainly been obtained not far from this result, but not with the same sureness of realizing it. Never has there been realized without superheating for an engine of 200 indicated horsepower, an expenditure of only 5,311.8 Fahrenheit units of heat per horsepower per hour. This figure corresponds to a thermal economy of $\frac{5,311.800}{2,508.718}=0.2117$.* Now the writer does not know of any steam engine whose thermal economy exceeds 0.194 for the indicated horsepower.†

Experience shows that, in general, superheating produces appreciable effects in steam engines of all types and of all powers, and that incontestably it increases their economy.

Nevertheless, the question should always be answerable, What is the exact economy obtained by superheating for steam engines of the best design and construction provided with steam jackets and using the steam in multiple cylinders? Is not superheating a superfluity in the case of steam engines in which already nothing has been neglected for preventing the injurious consequences of the interaction of the heat of the steam with the metal of the cylinder? Will the benefit then obtained be a sufficient justification for the use of a costly apparatus subject to rapid destruction, which is and will remain delicate for a long time, and which requires incessant and competent supervision?

To answer this question comparative experiments must be made having for special object the exact determination of the economy realized by the superheating in engines otherwise already excellent. Such experiments have been made

* The thermal economy is the fraction which the units of heat utilized are of the theoretical units of heat equivalent to the work done during the same time. The theoretical equivalent of heat for one horsepower exerted during one hour is $\frac{33,000\times 60}{789.25}=2,508.718$ Fahrenheit units of heat. The divisor is the mechanical equivalent of heat in foot-pounds per unit of heat.—TRANS.

† Gas motors give a much higher economic efficiency. Thus, the Catteau motor with which I recently experimented at Roubaix, consumed 317 liters of gas at 5.784 calories per cubic meter per hour per indicated horsepower. This is an indicated thermic economy of 0.346. It is exceptional, but economies of 0.300 are common, as I have shown in the January and June, 1902, numbers of "L'Eclairage Electrique," in the course of my studies on the comparative economy and functioning of thermic motors.

Table No. 2.—Comparative Consumptions by the Same Steam Engines Supplied First with Saturated Steam and Afterwards with Superheated Steam.

Type of engine.	Experimenters.	Saturated steam.				Superheated steam.					Gain by the superheating, in per centum of the units of heat expended with the saturated steam.
		Indicated horsepower.	Temperature of the steam, in degrees Fahrenheit.	Consumption per hour per indicated horse-power. In lbs. weight of steam.	Consumption per hour per indicated horse-power. In Fahr. units of heat.	Indicated horsepower.	Temperature of the steam, in degrees Fahrenheit.	Steam superheated, in Fahrenheit degrees.	Consumption per hour per indicated horse-power. In lbs. weight of steam.	Consumption per hour per indicated horse-power. In Fahr. units of heat.	
Single-cylinder Woolf	Walther-Meunier	357.662	318.29	22.0748	26,025.90	400.122	420.80	102.51	19.5329	24,230.43	6.899
Single-cylinder Corliss	Walther-Meunier	306.019	327.20	19.0501	22,512.65	304.638	430.70	103.50	15.7322	19,568.65	13.077
Compound Corliss	Walther-Meunier	549.665	331.88	18.7393	22,171.67	569.855	446.00	114.12	14 8812	18,774.66	15.321
Compound Corliss	Gyssling	566.570	332.24	14.9032	17,634.54	573.741	462.20	129.96	12.4120	15,654.61	11.228
Triple-expansion Frikart	Weber	689.434	371.62	13.6246	16,285.29	687.846	446.32	74.70	12.0372	14,927.40	8.338
Triple-expansion Corliss	Walther-Meunier	794.162	371.30	12.6722	15,145.69	798.104	550.40	179.10	10.3088	13,428.76	11.336
Compound Van der Kerchove	Schröter	216.029	356.54	12.0593	14,358.55	212.242	665.92	309.38	8.8626	12,097.40	15.748

by various persons, but the Alsatian Association of the Proprietors of Steam Apparatus so ably directed by Mr. Walther-Meunier, has furnished the most of the data for the solution of this important problem: the statement is made with pride that Alsace, after inaugurating the practice of superheating, has also the most effectively contributed to its general introduction and improvement.

The following table, No. 2, shows in parallel columns the results obtained, revolution for revolution, from the same engine with and without superheating, all other things being as near equal as possible.

The gain by superheating varies from 7.8 to 17.3 per centum, and there should be remarked that the order of classification of the engines is the same for saturated steam and for superheated steam, the economy increasing parallel in the two cases, the economy with superheated steam being a maximum for the engine which holds the first rank with saturated steam. The establishment of this fact has a significance which cannot be too much emphasized.

Table No. 3.—PROF. SCHRÖTER'S EXPERIMENTS AT GHENT IN 1902.

....	Saturated steam.	Superheated steam.				
Temperature in degrees Fahrenheit of the steam....................	356.54	399.74	452.48	506.12	583.52	667.04
Indicated horsepower developed.....	217.89	219.82	220.84	217.27	217.22	212.24
Pounds weight of steam consumed per hour per indicated horsepower..	12.23	11.73	11.15	10.82	9.97	8.99
Equivalent pounds weight of saturated steam consumed per hour per indicated horsepower............	......	11.94	11.60	11.49	10.89	10.10
Corresponding Fahrenheit units of heat consumed........................	14,557	14,219	13,800	13,668	12,955	12,038
Economy realized by the superheating, in per centum...	......	2.4	5.1	6.0	11.0	17.3

The experiments on the last line in the table deserves in other respects to arrest attention. They form part of an important series made by Professor Schröter in September, 1902,

in Ghent at the van den Kerchore shops on an engine with piston valves of which the small cylinder was without steam-jackets. These researches show the influence of a progressive superheating.

These experiments have been followed by others made with much higher degrees of temperature, and the economy obtained confirm the brilliant results that have just been described.

From an inedited memoir most obligingly communicated, the following experimental results are extracted.

Table No. 4.—INEDITED EXPERIMENTS COMMUNICATED TO THE AUTHOR.

....	Saturated steam.	Superheated steam.			
Pressure of the steam in pounds per square inch above the atmosphere..	129.29	129.86	130.57	131.42	130.00
Corresponding temperature of the steam in Fahrenheit degrees.........	357.24	357.55	357.98	358.39	357.76
Temperature in Fahrenheit degrees of the steam at the small cylinder..	352.45	490.46	584.24	647.42	734.00
Superheating in Fahrenheit degrees..	......	132.91	226.26	289.03	376.24
Indicated horsepower developed......	224.63	230.42	228.87	220.42	218.58
Pounds weight of steam consumed per hour per indicated horsepower	12.92	10.89	9.79	9.41	8.61
Fahrenheit units of heat consumed per hour per indicated horsepower	15,361	13,660	12,722	12,678	11,805

The temperature of 758.48 degrees Fahrenheit has even been attained, or 400.5 Fahrenheit degrees of superheat, and the consumption of steam has fallen to 8 pounds, corresponding to 11,071.56 Fahrenheit units of heat. Consequently, the maximum has not been at all reached, and the experiment shows decisively that still more economic gain could have been obtained had higher superheating been possible. Much importance can be attached to this experimental proof.

The law which M. Walther-Meunier announced in 1895 is thus solidly established, namely, that the consumption of heat per hour per indicated horsepower diminishes in measure as the temperature of the superheat increases, and the economy is continuously increased.

M. Dujardin, in another direction, has deduced from experi-

2

ments he has made on his workshop engine that, with variable engine load, the consumption of superheated steam remains constant per unit of power developed at both full power and at half power. The following quantities are decisive in this respect.

DUJARDIN'S EXPERIMENTS MADE TO DETERMINE THE INFLUENCE OF VARIABLE DEVELOPMENTS OF POWER UPON THE ECONOMY OF SUPERHEATING.

Pressure of the superheated steam, pounds per square inch above the atmosphere	85.337	125.161	99.560	71.114	85.337	103.826
Indicated horsepower developed	88.767	136.109	137.096	163.726	170.630	202.191
Temperature in degrees Fahr. of the superheated steam	509.000	550.400	527.000	518.000	518.000	545.000
Temperature in degrees Fahr. of the saturated steam	327.600	352.770	337.370	316.690	327.600	340.115
Number of degrees Fahr. of superheat	181.400	197.630	189.630	201.310	190.400	204.885
Pounds weight of steam consumed per hour per indicated horsepower	13.523	13.232	13.411	13.300	13.300	13.255

The experimental data now possessed in regard to superheating can, consequently, be summarized in the following laws:

1st. Superheating increases the economy of steam engines of all types; single cylinder, Woolf compound or triple expansion, even when they are provided with steam jackets applied under the best conditions.

2d. The economy increases with the number of degrees of superheating.

3d. The consumption per hour per indicated horsepower developed by the engine remains constant for full power and for half power.

Such are the facts that theory ought to explain.

A general consideration of the cycle of the steam engine shows in the first place that raising the temperature of the

steam above the saturation point would necessarily improve the economy.

The cycle of the steam engine does not respond to Carnot's concept, notwithstanding that the heat is imparted to the water by the furnace at the constant temperature which call T_1, after which it is reduced to the constant temperature T_2 by the condenser, which thus performs the office of refrigerant, the cycle of the steam engine is not the cycle of Carnot because it is not limited by two adiabatics. The fourth phase of the theoretical cycle, namely, that of comparison without either gain or loss of heat, and which ought to return the fluid to its initial state, is absolutely in default in the real cycle of the steam engine, for instead of returning at the temperature T_1 the mixture of steam and water remains in the condenser at the temperature T_2. That the cycle closes can be admitted, but it is not a reversible cycle. The case would then be known not to be a question of applying the formula of Carnot $\frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}$; there should always be observed, however, that to make this final compression would not be impossible, and to thus reintroduce into the boiler water at the temperature T_1; some English engineers have attempted it, and not without some success, and if they have renounced it, it is because they have shown that the solution of this problem has not a sufficient practical interest. We have then some right to still use the theoretical formula for remote approximations, and to retain for general indication the conclusions to which it leads; among them is the economic advantage of increasing the fall of temperature $T_1 - T_2$ by increasing T_1; now this is done by superheating the steam.

Having regard to the above reserves, let the value of the economy, which call ρ, be calculated for the case when the saturated steam has the temperature 327.2 degrees Fahrenheit (for 85.337 pounds per square inch above the atmosphere), and that of 495 and 666 degrees Fahrenheit of superheat, the condenser having the temperature 86 degrees Fahrenheit.

$$T_1 = 459.4^\circ + 327.2^\circ = 786.6^\circ \text{ Fahr. absolute.}$$
$$T_1 = 459.4^\circ + 527.0^\circ = 986.4^\circ \text{ Fahr. absolute.}$$
$$T_1'' = 459.4^\circ + 698.0^\circ = 1{,}157.4^\circ \text{ Fahr. absolute.}$$
$$T_2 = 459.4^\circ + 86.0^\circ = 545.4^\circ \text{ Fahr. absolute.}$$

$$T_1 - T_2 = 241.2^\circ \qquad \rho = 1 - \frac{545.4}{786.6} = 0.306$$

$$T_1 - T_2 = 441.0^\circ \qquad \rho = 1 - \frac{545.4}{986.4} = 0.447$$

$$T_1'' - T_2 = 698.0^\circ \qquad \rho = 1 - \frac{545.4}{1{,}157.4} = 0.529$$

Progressive superheating increases progressively the economy, and it could give in a steam engine functioning according to the cycle of Carnot an economy of 67 per centum for a superheat of 630 Fahrenheit degrees. The real machine is very far from realizing anything like this.

Let us see what we ought really to gain by superheating.

The economy of any cycle whatever can be calculated rigorously, provided that it be a closed cycle, by making it the quotient of the division of the heat transmuted into work by the heat obtained from the furnace, that is to say, by the aid of the formula $\frac{Q_1 - Q_2}{Q_1}$, Q_1 being the heat obtained from the furnace, and Q_2 being the heat carried to the refrigerant.

Now, we have the means of calculating exactly Q_1 and Q_2.

Suppose the cycle to be traversed by a mixture of one pound weight of steam and water.

This pound is delivered into the condenser in the liquid state at the temperature t_2,* and from the condenser it is pumped into the boiler where the water is raised from the temperature t_2 to the temperature t_1 and vaporized. But the saturated steam is not, generally, furnished in the dry state to the cylinder, which receives a mixture of steam and water containing a fraction x_1 of steam and a fraction $1 - x_1$ of water.

This mixture carries with it the quantity of heat equal to

* The letters t designate thermometric temperatures, and the letters T designate absolute temperatures.

$\int_{t_2}^{t_1} C dt + x_1 r_1$; C is the specific heat of the water, and r is the heat of its vaporization at the temperature t_1; if C be assumed to be constant,

$$Q_1 = C(t_1 - t_2) + x_1 r_1.$$

This mixture acts upon the piston, first at full pressure, then it expands, passing from the pressure p_1 in the boiler to the pressure p_2 in the condenser, and from the corresponding temperature t_1 in the boiler to the corresponding temperature p_2 in the condenser. Clausius and Hirn discovered that this expansion is fatally accompanied by a partial liquefaction which lowers the composition of the mixture from x_1 to x_2. Clausius demonstrated that x_2 is determined in function of x_1 by the formula

$$\int_{T_2}^{T_1} C \frac{dT}{T} + \frac{x_1 r_1}{T_1} - \frac{x_2 r_2}{T_2} = 0.$$

The value of x_2 is then known.

The condenser liquefies the whole of the mixture; consequently $x_2 r_2$ is retired; it is the quantity Q_2.*

We have therefore:

$$\rho = \frac{Q_1 - Q_2}{Q_1} = \frac{C(t_1 - t_2) + x_1 r_1 - x_2 r_2}{C(t_1 - t_2) + x_1 r_1} = 1 - \frac{x_2 r_2}{C(t_1 - t_2) + x_1 r_1}.$$

In this manner is calculated the economic performance ρ of a steam engine supplied with saturated steam of the composition x_1.

In the case of superheating $x_1 = 1$; further, the superheating costs in heat $C(t_1' - t_1)$, C being the specific heat, supposed constant, of the steam, and t_1' the temperature of the superheating.

We have, then:

$$Q_1 = C(t^1 - t_2) + c(t'_1 - t_1) + r_1.$$

*The two terms Ap_2, ux_2, which cancel, are not mentioned; on the other hand, the work is neglected of feeding the boiler, which is the same for saturated and for superheated steam, and is, moreover very small.

In expansion, the steam gradually loses its superheating and passes to saturation, ending, finally, with a composition that may be called x'_2 to distinguish it from x_2; x'_2 is evidently greater than x_2.

The rest of the calculation is identical with the preceding.*

We have, then:

$$\rho = 1 - \frac{x'_2 r_2}{C(t_1 - t_2) + c(t'_1 - t_1) + r_1}.$$

To render account of the effect produced by the superheating, the respective values of ρ and ρ' must be determined for a concrete example; for this purpose, replace the symbols by the numbers below given.

$$t_1 = 327.2^\circ \text{ Fahr.} \quad t_2 = 86^\circ \text{ Fahr.} \quad t_1 - t_2 = 241.2^\circ \text{ Fahr.}$$
$$r_1 = 883.19 \qquad r_2 = 1054.12$$
$$C = 1.013$$

Take $x_1 = 0.95$, the value habitually assumed; the formula of Clausius gives $x_2 = 0.79$.

All calculations being made, there results from the processes of saturated steam:

$$\rho = 1 - 0.768 = 0.232.$$

In superheating, $t_1 = 662^\circ$, $c = 0.48$, $x'_2 = 0.248$.

The gain is then equal to about 7 per centum.†

Before discussing that result, the observation can be made that the calculations furnish a most valuable indication; they show that in an expansion from the pressure corresponding to the saturation temperature of 327.2 Fahrenheit degrees to the pressure in the condenser corresponding to the saturation temperature of 86 Fahrenheit degrees, even when accompanied by a superheating to 662 Fahrenheit degrees, the

* In the calculations no account is taken of the action of the steam jacket, the heat from which contributes, in a certain measure, to lessen the liquefaction in the cylinder.

† Regnault adopted for the specific heat c of superheated steam, the constant value 0.48, which is employed in our calculations; but this coefficient very probably increases with the temperature, and that at 662 Fahrenheit degrees it should be much greater, thereby largely increasing the economy.

steam loses its entire superheating, and its composition falls to 0.92. This does not happen in the case of a less complete expansion. Thus, I have established for an engine using its steam without condensation, and with superheating to 689 Fahrenheit degrees, exhausting into the atmosphere at the temperature 244.4 Fahrenheit degrees* ; that the phenomenon would be less marked in practice, because the steam is rarely expanded to the pressure in the condenser; nevertheless, there can be said that the superheating ordinarily given is insufficient to remain to the end of the stroke of the piston. To obtain such a result the superheating would have to be carried much higher than 662 Fahrenheit degrees.

What is this exact temperature?

Thermodynamics can furnish an answer to this question.

Clausius asserts that superheated steam expands like a gas, and that the formula of Poisson, $pv^\gamma =$ constant, is applicable to it, provided the exposant γ be made equal to 1.28; from which results that the absolute temperatures and the corresponding pressures are related as expressed in the known formula:

$$\frac{T_1'}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}}.$$

Substituting centigrade numbers, there are found:

$$T_1' = 303\left(\frac{7}{0.0429}\right)^{0.218} = 920^\circ \text{ absolute} = 647^\circ \text{ centigrade.}$$

In a steam engine using the steam with condensation and with complete expansion, and without having regard to the action of the steam jacket, for the steam to reach the end of the stroke of the piston in an absolutely dry state would require a superheating to above 1,100 Fahrenheit degrees. The latest experiments may perhaps realize such a temperature; if they do, they are to be congratulated because, in that case,

* The experiment was made on a small Buffaud and Robatell engine furnished with steam from a Serpollet superheating boiler. I experimented with this engine at Paris in 1896; it consumed 13 15 pounds weight of steam per hour per indicated horsepower, under a pressure of 200 pounds per square inch above the atmosphere.

the value ρ of the economy would receive a remarkable increase, inasmuch as the calculation then gives

$$\rho = 0.375,$$

and the economy of the gas engine would be surpassed.

It is absolutely true that at the present time the case which has just been considered is wholly fictive and merely theoretical, but the advocates of steam will, without doubt, remember the deductions made from our calculations. Others will be content to note that the theory is in accord with practice, because there has been experimentally shown that a continually increasing economy results from a continually increasing superheating up to at least 750 Fahrenheit degrees.

But they will also remark that the economy promised by calculation has been less than that which has been experimentally realized. This fact is interesting because speculative calculations, such as those which have just been made, ought to give results greater than those furnished by experiment, because they apply to only perfect machines free of wastage.

How does it happen that while the calculations predict only 7 per centum of economy, 18 per centum are often experimentally obtained?

Are the calculations false, or are they incomplete?

We shall see that they are incomplete.

Hirn had, in fact, already encountered similar divergences between theories and facts, and he had been led in a manner to declare that all those theories which he called *generic* were insufficient, because they omitted a capital element in the question, namely, *the interaction of the metal of the cylinder with the heat of the steam.*

There remains, then, for us to include in the study of the phenomena which take place within the cylinder this preponderating influence of the metal in contact with which the steam evolves in its cycle, in applying the experimental theory of the master.*

* WITZ. De l'effet thermique des parois d'une enciente sur les gaz qu'elle renferme: Thèse inaugurale soutenue devant la Faculté des Sciences de Paris, et Annales de chimie et de physique. 5e série. Tome XV. 1879.

The superheating of steam has for first effect, the transformation of an immediately condensable fluid into a gas capable of parting with a considerable quantity of its heat without liquefying; and I demonstrated in 1878, that the non-liquefiable gas lost less of its heat by its contact with the metal of the cylinder which enclosed it, than liquefiable vapors lost under the same circumstances: the action of the metal of the cylinder is then less on the superheated steam than on the saturated steam, and the expansion the more closely approximates the adiabatic state.

But this is the small side of the question, for there is another consideration still more decisive, and another influence still more energetic. When the steam has arrived in the state of saturation at the end of its expansion, it has deposited a fine dew on the interior surfaces of the cylinder; this dew vaporizes at the moment the cylinder is put in communication with the condenser, taking the necessary heat for this purpose from the metal of the cylinder, and this phenomenon occasions the loss which Hirn called *the cooling by the condenser.* This is the loss which most contributes to the lessening of the economy of the steam engine. "The most disastrous cause of the loss of heat," said Hirn, "is the instantaneous vaporization of the water which remains on the metallic inner surfaces of the cylinder at the end of the expansion, and at the moment of the exhaust to the condenser."*

This vaporization has for immediate result so great a cooling of the metal that it produces at the beginning of the following cycle, during the consecutive admission, an abundant liquefaction of steam, which lowers the composition of the freshly-admitted steam, wets again the inner surfaces of the cylinder, and aggravates the evil until the regimen is established. These phenomena constitute the gravest cause of the deterioration of the cycle; the quantity of heat lost in this manner can much exceed the quantity of heat transmuted into work.

*Hirn. Exposition analytique et experimentale de la Theorie mechanique de la chaleur. 3d edition. Tome II, page 65. Paris. 1875.

Now, it is evident that this deterioration is so much the more important as x_2 is more feeble; it is greatly reduced by the superheating, since x'_2 is always greater than x_2.

But this is not all: if the superheating of the admitted steam be such that (t'_1-t_1) is greater than the cooling to the condenser, the steam will not liquefy during the period of admission, from which will, consequently, result a considerable economy entirely neglected by the generic theory, which to that extent is incomplete.

We can thus understand why the calculation gives only 7 per centum of economy, while experiment sometimes gives 17 per centum.

The constancy of the consumption of superheated steam, found at half power and at full power, is explained by the same considerations; the saturated steam x_2 is so much the more feeble as the expansion is more nearly complete, and its value ought to diminish with the power developed; this is why the consumption at half power is always greater than at full power. But when the steam is superheated the variation of x'_2 is much less marked, and economy varies only insensibly.

Since x'_2 is never equal to 1, by default of sufficient superheating, the employment at the same time of steam jacketing and of multiple expanding will consequently remain useful; superheating should then always be economical for all steam engines under all conditions, as practice has demonstrated it to be.

But its effect is not much in the small cylinder of compound- and triple-expansion steam engines, the internal liquefaction being produced chiefly in the following cylinders. It would then be rational to superheat the steam in the *receivers* during its passage from a preceding to a succeeding cylinder, as proposed by the Messieurs Sulzer, and which seems to have been successfully done in Germany.

The experimental theory completing the conclusions derived from the generic theory sufficiently accounts for the different particularities observed in the processes of superheating, and explains the economy realized, which results from the greater

fall of temperature between the boiler and the condenser, from the best conditions for the expansion and, principally, from the diminution, if not the complete suppression, of the cooling to the condenser.

These considerations are of a nature to encourage practical engineers to continue their experiments and to persevere in their attempts; the great object is to perfect the superheaters, and to construct engines that allow the use of high temperatures without losing their certainty in functioning, which is the most important quality in steam engines. The ablest engineers are now engaged on this task, and there is hope they may succeed.

Meanwhile, all users of steam power are interested henceforth in adding superheaters to their boilers, and a very moderate degree of superheating will suffice to produce appreciably good results with any kind of steam engine.

NOTE BY TRANSLATOR.

The experiments in the Author's Table No. 1, can hardly be considered as comparative, though very interesting in many respects. Such experiments to be comparative, should be described in greater detail and the data should be complete. Moreover, in the cases of using saturated and superheated steams, several of the conditions, especially, should be the same or very nearly the same, namely, the pressure of the steam, the number of double strokes made by the pistons per minute, the measure of the expansion with which the steam is used, and the temperature of the feed water. Of course the type of engine should be the same, and the steam jacketing should be the same. No statement is given as to whether the cylinders were steam jacketed or not, nor with what measure of expansion the steam was used. The temperature of the feed water is not stated, and the calculation of the results from the heat consumed had to be made on the supposition that in all cases this temperature was 32 degrees Fahrenheit.

The importance of the knowledge of all the facts of the experiments may be estimated by the following economic effects depending on them:

The loss of steam by leakage past the valves and pistons of the cylinders varies with the pressure of the steam in them, other things being equal. The greater this pressure the greater this loss, which latter is a considerable item with all steam engines. Then, on the contrary, the greater the initial pressure in the cylinders, other things equal, the greater will be the ratio of the mean utilized pressure to the mean total pressure, the latter being measured down to the zero of pressure; the non-utilized pressure being the sum of the mean back pressure against the piston and of the pressures due to the two kinds of friction opposing the movement of the piston; that is to say, the sum of the pressure required to equilibrate the friction of the moving parts of the unloaded engine and the friction of the load, the latter being as the load, while the former is as the weight of the moving parts of the engine. Both these frictions are measured in the mean indicated pressure on the piston, as shown by the indicator-diagram. As the greater the initial steam pressure in the cylinder the greater the economic loss by leakage and, also, the greater the economic gain by the greater fraction of the total pressure utilized, this loss and this gain, both due to higher pressure, may be considered, in measure, to offset each other. Also, the higher the steam pressure the greater the economic loss by the external radiation of heat. And, finally, as the greater the initial pressure in the cylinder the more expansively the steam can be used, with the corresponding economic gain, but with the inevitably accompanying economic loss due to the increasing interaction of the heat of the steam with the metal of the cylinder as the expansion increases; the gain and the loss thus produced may also be taken in measure to offset each other.

All practical experience, however, shows that increased reciprocating speed of piston and increased pressure of steam, either separately or combined, are factors of value in the pro-

duction of economic efficiency in the case of steam engines, independently of other conditions, and that for the determination of comparative economic results effected by other conditions, equality in these particulars is essential.

The use of Table No. 1 for the purpose for which it is given, namely, the comparison between the economy obtained from saturated and from superheated steam, in order to show the gain by the latter, the comparison in question must be limited to the mean data of the experiments made with multiple-cylinder engines using the steam with condensation, and having steam jackets in both cases. This limitation reduces the comparison to the mean of the last five experiments made with saturated steam, and to the mean of the last six experiments made with superheated steam, with the exception of the experiment in which the items were not complete.

MEAN DATA OF FIVE EXPERIMENTS WITH SATURATED STEAM.

Number of double strokes made by the pistons per minute........	61.577
Pressure of steam, in pounds per square inch above atmosphere..	103.46
Indicated horsepower developed by engine..............................	567.497
Temperature, in Fahrenheit degrees, of the saturated steam......	338.89
Pounds weight of steam consumed per hour per indicated horsepower........	12.8869
Fahrenheit units of heat consumed per hour per indicated horsepower........	15,274.46

MEAN DATA OF FIVE EXPERIMENTS WITH SUPERHEATED STEAM.

Number of double strokes made by the pistons per minute........	91.080
Pressure of steam, in pounds per square inch above atmosphere..	148.69
Indicated horsepower developed by engine..............................	515.022
Number of Fahrenheit degrees that the steam was superheated..	220.14
Temperature in Fahrenheit degrees of the superheated steam....	548.83
Pounds weight of steam consumed per hour per indicated horsepower........	10.7599
Fahrenheit units of heat consumed per hour per indicated horsepower........	14,150.97

ECONOMIC RESULTS.

The economic gain due to the superheating was, according to the above comparison,

$$\left(\frac{15{,}274.46 - 14{,}150.97 \times 100}{15{,}274.46} = \right) 7.355 \text{ per centum}$$

in function of heat expended for the production of equal power.

If the steam jackets be supposed to have wholly prevented "cylinder condensation," and if the difference of the conditions of the experiments with saturated steam and with superheated steam be considered to have had no economic influence on the result, then this gain of 7.355 per centum was due to the superior economy obtained by the experimental amount of superheating, namely, 220.14 Fahrenheit degrees imparted to saturated steam of the pressure of 148.69 pounds per square inch above the atmosphere, over the economy obtained with saturated steam alone, the expenditure of heat being the same in both cases. In other words, under the particular conditions of the experiments the same quantity of heat expended in the two cases gave 7.355 per centum more power when superheated than when saturated, showing an economic superiority of that much for superheating alone. But this amount of economic gain applies only to these particular experiments, and cannot be predicted as true for comparative results obtained under other conditions.

The number of Fahrenheit units of heat equivalent to one horsepower exerted during one hour, the mechanical equivalent of heat being taken at 789.25 foot-pounds per unit of heat, is ($33,000 \times 60 \div 789.25 =$) 2,508.72. The Fahrenheit units of heat consumed per hour per indicated horsepower when saturated steam was used was 15,274.46, consequently in this case ($15,274.46 \div 2,508.72 =$) 6.088 times the academic quantity of heat was practically used, or ($100 \div 6.088 =$) 16.426 per centum of the heat consumed was converted into indicated work, which is about the average economic result given by steam-jacketed, multiple-cylinder condensing engines.

Proceeding in the same manner for the case when superheated steam was used, there results that of the heat practically expended, 17.730 per centum was converted into indicated work.

In these comparative experiments, the economic effect produced by the considerable superheating given to the steam

appears small, certainly it could not have been less than the 7.355 per centum obtained; assuming the experimental data to be correct, and there is no reason to doubt it, then the differences that existed between the conditions when saturated steam and when superheated steam were used must, as regards the final economy, have such compensations in the matter of gain and loss as to practically neutralize them, causing the economic results to be the same as though these economic conditions were alike in both cases; a very interesting and not at all improbable conclusion. The experimental gain must be distinctly understood as applicable only to the exact conditions existing during the experiments, and cannot be assumed as what would be obtained under other conditions.

Although the first series of experiments were made with strictly saturated steam, yet they had the benefit of whatever gain was due to the steam jacketing.

The last series of experiments were made with superheated steam, but they, too, had the benefit of whatever gain was due to the steam jacketing.

Consequently, the results of the comparison is really the gain which the superheating effected above the gain due to the steam jacketing. These results are, therefore, considerably different from what they would have been had there been no steam jacketing in either case.

The economic effect of properly applied steam jacketing is the prevention of "cylinder condensation." Now, this prevention constitutes a large part of the economic benefit of superheating, which is correspondingly lessened by its prevention, thus leaving only the benefit due to the superheating really as such. Moreover, although the superheating apparatus was placed between the boiler and the chimney, and the steam was superheated by the waste heat in the chimney gases, yet that heat was computed and charged to the cost of the power. Both of these processes made the economic result of the superheating less than it would have been had there been no steam jacketing in either case, and had no charge

been made of the waste heat in the chimney gases utilized for the superheating.

The superheating surface was placed between the boiler proper and the chimney, so that the superheating was done by waste heat from the boiler after the hot gases of combustion had left it, in which case the practical economic gain, as distinguished from the academic economic gain due to the superheating, would have to be ascertained from very different factors than in the foregoing comparison.

The heat expended in the superheating of the steam has been calculated as the product of the difference of the temperatures which the steam had between the beginning and the end of the superheating, into the pounds' weight of steam superheated per hour, into 0.6, which fraction is assumed in the absence of exact determinations, as the specific heat of superheated steam under constant pressure, and constant for all temperatures. Any error due to the uncertainty of this fraction will be very small. This superheating heat has, in the preceding comparison, been added to the heat of the steam normal to the pressure of the superheated steam, the sum of the two being taken as the cost in heat of producing the superheated steam. But, practically, when the superheating is done by waste heat escaping from the boiler this superheating heat should not be added, and the comparison of the economic results should be made by taking for the heat-cost of producing the two steams only the heat of the generation of the saturated steam.

In the case of the superheated steam in the previously given comparative data, of the 14,150.97 Fahrenheit units of heat consumed per hour per indicated horsepower developed by the engines ($220.14 \times 0.6 \times 10.7599 =$) 1,421.21 Fahrenheit units of heat were contributed by the superheating done in the superheater, the remaining ($14,150.97 - 1,421.21 =$) 12,729.76 Fahrenheit units of heat being contributed by the vaporization of water in the boiler.

In the case of the saturated steam in the previously given comparative data there were consumed per hour per indicated

horsepower developed by the engines 15,274.46 Fahrenheit units of heat.

Consequently, the indicated horsepower cost in the case of the superheated steam $\left(\frac{15{,}274.46 - 12{,}729.76 \times 100}{15{,}274.46} =\right)$ 16.66 per centum less than in the case of the saturated steam, which, as this percentage represents the gain in fuel consumed, may be taken as the commercial value of the superheating as done. Of course, $(16.66 - 7.355 =)$ 9.305 of the 16.66 per centum of gain was due not to the superheating but to the use of heat that would have otherwise been wasted.

When experiments in progressive steam-superheating are made on the same steam engine developing the same constant number of horsepowers with steam of the same pressure, and with all other conditions the same except the degree to which the steam is superheated, the weight of water vaporized in the boiler, per horsepower developed by the engine, decreases in the proportion in which the superheating increases. This is due to the fact that the same pressure being preserved, the more of the work done by the superheat of the steam, the less must be the work done by the generation of the steam, the sum of the two being a constant. Consequently, superheating the steam does not increase the power of the same engine doing the same work in the same time, but it increases the economy with which that work is done.

Among the advantages of superheating not mentioned by the author, should be included the saving effected by it in the first money cost and in the repairs afterwards, and in the sinking fund, of the boiler; equal quantities of steam of equal pressure and better quality being furnished by it in equal time. This saving would be about one-sixth, as determined by the experimental data, in which case the superheating was done by waste heat in the chimney gases. For marine purposes, the lessening of the boiler by one-sixth, its development of power remaining the same, is a very serious gain otherwise, as it saves one-sixth of the weight and volume of the boiler in the vessel. Further, one-sixth of the weight and

3

volume of the coal required for equal distances traversed by the vessel in equal time, would also be saved. The author insists only on the heat saving effected by superheating per unit of power developed, which, indeed, is the great point of interest with land boilers, and they are the special objects of his investigations; but the gain obtained by superheating is really of much more importance for marine boilers, as has been just pointed out, and the field is nearly as wide. Of course, from the space and weight saved in the boiler alone, there must be deducted the weight and space of the added superheating apparatus, but for the saving in the weight and space of coal carried, no deductions are to be made. The money cost, however, of the superheating apparatus must be deducted from the cost of the part of the boiler saved by it.

The comparison for weight must be when the superheating apparatus is not used, the aggregate weight of boiler including its contained water and the weight of the coal required; and when the superheating apparatus is used, the aggregate weight of boiler, including its contained water, the weight of the superheating apparatus and the weight of the coal required. The comparison for space must be made on the same basis.

The comparison for money cost must be made simply for the boiler alone when the superheating apparatus is not used, and for the aggregate boiler and superheating apparatus when the latter is used.

Additionally, there must be considered the money value for cargo purposes of the space and weight saved in the vessel. And, also, the money value of the coal saved for all the steaming done by the vessel during the life of the superheating apparatus.

As the temperature of the chimney gases is usually high enough to give as great a degree of superheating as can safely be permitted in average practice and under ordinary supervision, the heat in those gases, and which would otherwise be lost, should be utilized, instead of employing a superheater with an independent furnace, and a specific consumption of coal to produce the superheating.

It is quite true that the addition of the heat-absorbing surface of the superheater to the water-heating surface of the boiler would utilize a part of the waste heat escaping in the chimney gases by evaporating more saturated steam; but the economy obtained would not be as great, and for two reasons: 1st. To produce a given pressure, more heat must be imparted to the water for the generation of saturated steam than is required for the superheating of this steam. 2d. When taken in connection with the steam engine, the given volume of saturated steam of given pressure could not develop as much power as would be obtained from the superheated steam, because the steam produced in the first case would be saturated steam which would partially liquefy on the slightest abstraction of heat, while the superheated steam could, without any liquefaction, be reduced in temperature by the abstraction of heat until the whole superheat had been taken out.

The use of sufficiently superheated steam, therefore, prevents liquefaction in the cylinder and the economic loss attending it; for as long as the temperature of the steam in the cylinder is above the saturation temperature, there cannot be any "cylinder condensation." Now, whatever water of liquefaction may be deposited on the inner surfaces of the cylinder, the same has to be revaporized by heat taken out of the metal of the cylinder, which heat in turn has to be restored during the next stroke of the piston by latent heat taken out of the steam entering the cylinder from the boiler, consequently, the whole of this heat is lost for the production of power.

From the foregoing appears that superheating the steam causes two entirely distinct economic effects in the steam engine; one, negatively, as a preventive of a loss ("cylinder condensation"); the other, positively, as a productive of gain (the greater external work done by a given quantity of heat in the expansion of the gas superheated steam than in the expansion of water into saturated steam); but the two are only necessarily combined when saturated steam is used in the cylinder.

Suppose the cylinder to be efficiently steam jacketed (which can always be effected by filling the jacket with saturated steam of higher pressure than the saturated steam which enters the cylinder), so that a sufficient additional quantity of heat be passed from the steam in the jacket into the steam in the cylinder to maintain the latter steam above the saturation temperature, then superheated steam from a superheater could not act preventively by suppressing "cylinder condensation," as this would have been done already; consequently, this source of gain could not, in such a case, be credited to the superheated steam drawn from the superheater. But this latter steam would still produce the economic gain due to the greater power effect of superheated steam over saturated steam caused by the fact that substantially the whole of the superheat is sensible heat and does external work, while in the case of saturated steam a large portion of the heat becomes latent during the conversion of water into steam.

"Cylinder condensation" is wholly due to, and is in proportion to, the use of saturated steam expansively, and by reason of the continuous fall in the pressure and, consequently, in the temperature of the expanding steam; this fall of temperature making possible the interaction between the heat in the expanding steam and the metal of the cylinder with which that steam is in contact, whereby the heat taken out of the metal at one time by the expanding steam has to be replaced in the metal at another time by heat taken out of the entering boiler steam; the process occurring through the intermediary of the liquefying of the saturated steam and the revaporizing of the water of that liquefaction. The economic loss by the process consisting of the latent heat of the reevaporated steam, which passes into the condenser without doing external work.

If saturated steam were not used expansively, there would not be any "cylinder condensation," supposing no radiation of heat from the external surfaces of the cylinder and no "working over" of water from the boiler.

The purpose of steam jacketing is to add heat taken out of

its steam to the expanding steam in the cylinder, thereby preventing partial liquefaction of this latter steam and the consequent economic loss due to the revaporization of the water of liquefaction, the steam of which passes into the cylinder without doing external work.

The author has entirely ignored the serious loss in all steam engines by leakage of steam past the valves and piston of the cylinder. He attributes the difference between the weight of steam present as such in the cylinder at the closing of the cut-off valve as shown by the indicator, and the weight of steam drawn from the surface condenser per stroke of piston, wholly to what is termed "cylinder condensation," while, in fact, this difference is the sum of the leakage referred to and of the liquefaction due to the interaction between the metal of the cylinder and the heat of the steam, technically known as "cylinder condensation." The proportion of leakage does not admit of calculation, as it is due to imperfect workmanship and to the distorting action of the temperature of the steam upon the organs mentioned of the cylinder; besides which, it is mainly a steady "blow-through" from valve chest to condenser without interruption so that it is relatively less with greater reciprocating speed of piston. The proof of this leakage is the universally-recognized fact that the greater the number of double strokes made by the piston in a given time, the greater the economy with which the power is developed, other things remaining the same. In other words, the greater the number of double strokes made by the piston ,per unit of time the greater in direct ratio will be the power developed, while, as the leakage is sensibly constant per unit of time, it will *proportionally* affect the economy because there will be a larger and larger power to distribute the constant leakage among. If the engine functioned absolutely without leakage, the economy of its performance would not be affected by the reciprocating speed of its piston.

As a general fact the sum of the leakage and of the "cylinder condensation" may be taken for an example at, say, 21

per centum of the water of liquefaction drawn from the condenser, and of this 21 per centum at least one-third is probably leakage, leaving 14 per centum for the "cylinder condensation"; the loss of heat by the latter would then be the product of the number of pounds of water corresponding to this 14 per centum by the latent heat of the steam in the boiler.

Suppose the "cylinder condensation" to be 14 per centum of the water of liquefaction drawn from the surface condenser, then an economy of 14 per centum would be roundly the utmost that could be obtained by an amount of superheating just sufficient to prevent it, the superheating being done by heat taken from the hot gases of combustion in the chimney. If the superheating be done by an independent furnace the weight of coal consumed for that purpose in this furnace must be added to the weight of coal consumed in the boiler for the generation of the steam. The proper comparative commercial measurements now become the *aggregate* weights of coal consumed in boiler and in superheating furnace when the steam is superheated in that manner, and the coal consumed in the boiler alone when there is no superheating. The quotients of the division of the respective external work done by the engine, into these two quantities of coal, expresses the relative economy obtained by the superheating.

A comparison of the respective *units of heat* consumed in these two cases will give the relative economy as regards number of heat-units used, but not as regards the weights of coal required, to experimentally produce them; for, evidently, in the case of superheating by a separate furnace there would have to be burned the coal in the separate furnace required to produce the superheating, while, if the superheating be done by otherwise waste heat in the chimney-gases no additional coal would be required for that purpose, and whatever additional power might thus be obtained would appear to have been had for nothing.

If, however, the purpose be to obtain a higher superheating temperature than the chimney-gases can supply, then the independent superheating furnace with its specific additional

consumption of coal is a necessity; but the question arises whether the less superheating done by the chimney-gases without special expenditure of coal for the purpose is not economically equal to the greater superheating obtained in the independent furnace by the direct expenditure of the additional coal required to produce it?

The highest limit of temperature which the metal and the organs of the engine and of the superheating apparatus can bear without injury under the worst circumstances to which they will be subjected during prolonged use, and the mean temperature of the gases in the chimney, which varies for different conditions, but within comparatively narrow limits, are the two factors of the answer to the foregoing question. The limit of temperature referred to is soon reached, and beyond that limit the investigation of the economy due to still higher degrees of superheating becomes merely academic.

The results of short experiments made under carefully prepared conditions, and under the supervision of competent experts, cannot be accepted for prolonged service under the conditions that must be met in average practice.

Within reasonable limits of superheating, the heat for that purpose being taken without cost from the waste heat in the chimney gases, the use of superheated steam gives an economic gain which should never be neglected, especially as the superheat will never be sufficiently great to endanger the integrity of the machinery. The translator makes this affirmation as the invariable result of his own very great practice in this direction with an extensive variety of superheating apparatus. In his designs the temperature of the superheated steam was always kept well below temperatures prejudicial to either superheater or engine. He was content with moderate gains, and always kept in view that reliability was the first virtue of a steam engine whether on land or sea. He never had an accident with any of his superheaters, and all performed in a satisfactory manner.

THE ENGINEERING SITUATION IN THE UNITED STATES NAVY.

By Lieutenant Henry Charles Dinger, U. S. Navy, Member.

It has been my endeavor in writing this article to place before my readers a general description of the actual engineering conditions in the U. S. Navy; and, from this standpoint, to explain remedies that appear necessary, desirable and adequate to cope with present deficiencies, as well as, if possible, to call attention to certain threatening conditions that seem to be largely overlooked, and to strengthen the warning cry against various proposed plans of remedy which are not based on sound principles. Little is accurately known by the general public interested in naval matters of the present engineering conditions in the Navy, though the subject is continually being commented upon. Newspaper articles, reports and editorials are appearing unceasingly, ardently discussing present and past conditions, advocating some remedies and criticizing others that are proposed. Recommendations more or less antagonistic to each other are also appearing from various authoritative sources in the Navy.

Such an amount of criticism and discussion alone must impress the interested observer with the fact that there must be something wrong somewhere; but if the seeker after knowledge desires to find out just what is wrong, what persons are responsible for it and what conditions have brought it about, he will find from the literature now extant that opinions seem to be bitterly opposed, that apparently there is no concensus of opinion on the part of those who, to his mind, ought to know; and, also, that no harmonious act of legisla-

tion or regulation of the Navy Department has been presented which would solve the problem.

In his annual report for 1905 the Chief of the Bureau of Steam Engineering, Rear Admiral Rae, made certain recommendations concerning the engineering personnel, as follows:

"PERSONNEL.

"Again I consider it my imperative duty to invite the attention of the Department to the critical condition of engineering in the Navy.

"That this subject must receive serious and immediate attention, the deplorable accident on board the U. S. S. *Bennington* most forcibly emphasizes.

"Five and one-half years ago a momentous step was taken regarding the performance of duty in the Navy. A whole corps of specialists was virtually abolished, and the duties performed by these specialists were transferred to the line. The intent of the so-called 'Personnel bill,' the instrument by which the Congress authorized this change, was that all the younger officers of the Engineer Corps, the corps in question, were to perfect themselves in seamanship, gunnery and navigation, and were thereafter to perform both line and engineering duties indiscriminately, and at the same time the younger officers of the line were to perfect themselves in engineering and thereafter, likewise, perform indiscriminately the joint duties. The older officers of the Engineer Corps, although transferred to the line at the same time, were for obvious reasons to continue in the performance of engineering duty only. Thus eventually the line would be wholly composed of officers fitted to perform all duties connected with the movement of ships.

"The younger officers of the Engineer Corps were given two years in which to qualify for these new duties. How well they did it the records of the examining board and the fitness reports on officers bear striking testimony. As all midshipmen at the Academy had been given for years excellent prac-

tical instruction in engineering, no examination, other than that required for promotion, was demanded of them for qualifying for the performance of these joint duties. The intent was, however, that they should be ordered at once to the performance of this duty in subordinate capacities, as assistants of the older engineer officers.

"Owing to the absence of specific instructions to that effect in the personnel bill, combined with powerful adverse influences within the Department, for three years absolutely nothing was done by the younger line officers in acquiring engineering experience, and later, owing to the large number of ships kept in commission and the scarcity of officers, but little in that direction was accomplished.

"So long as the older officers of the former Engineer Corps remained available for service at sea, supplemented by a new body of warrant officers called warrant machinists, the engineering duty of the fleet was properly performed. Credit must not be withheld also from a few officers of the line who by their own personal exertions perfected themselves in engineering, and served, or are serving, with marked efficiency in most responsible engineering positions afloat.

"The older officers of the late Engineer Corps are rapidly disappearing from active service. In my last annual report I stated that there were 66 such officers at that time. The number has since been reduced to 43, and were it not that the services of certain retired officers are available, the Bureau would already be experiencing great difficulty in finding officers for the various responsible positions both on shore and at sea.

"So few officers of the line are taking up engineering seriously that the situation is becoming alarming.

"That the Department must do something to relieve this situation, and do that something at once, is only too obvious to the most casual observer of present conditions. Were the country suddenly plunged in war the Navy would find itself in no condition to win battles. As necessary as good marksmanship is the ability to carry our guns to the firing line

and to keep them there amidst the havoc created by modern ordnance, and this will never be done with amateurs in charge of the machinery. That line officers can become good engineers has already been proved, but they must have experience to become so, and that experience must be acquired in subordinate positions. No young officer out of the Academy but a short time, who would not be given charge of the deck except under the supervision of a senior officer, should be placed in charge of the engineer department of a ship, as has been done.

"Engineering logically belongs to the line, and the line should be made to perform that duty earnestly.

"In addition to the care and manipulation of the machinery of ships at sea, there are other duties which the engineer must perform and for which he must be fitted; these duties are the designing, inspection and superintendence of construction of that machinery. The Bureau holds, and it is not alone in the opinion, that the most successful designers of marine machinery are those who have had charge of it at sea.

"It therefore considers it most necessary that in the line of the Navy there should be a certain number of engineering specialists—officers who devote all their time and attention to engineering, for in this way only can the most competent designing engineers be obtained.

"As before stated, the situation is critical, and something must be done. The Bureau therefore submits the following plan for quickly supplying the Navy with a body of efficient engineers:

"All the younger officers of the line must be given engineering duty, and must be made to realize the importance of their responsibility. This duty must be at first in a subordinate capacity, and no officer should be given charge until his record shows his fitness for such duty. The examining board must be strict in its examinations for promotion, and before the board engineering must rank with seamanship, gunnery and navigation.

"That in the line there shall be a number of engineering

specialists, whose duty, both at sea and on shore, shall be engineering. These officers shall not perform duty at sea after reaching the rank of commander. A careful study of the necessities of the case has resulted in fixing the number of such officers at one in every ten above the rank of lieutenant, junior grade. These officers shall be recruited at the foot of the list of lieutenants—that is, when ten officers reach the rank of lieutenant below the last engineering specialist, the Department shall order an examination to be held of so many of those ten who volunteer for it for the purpose of selecting one officer to be assigned permanently to engineering duty. In case there are no volunteers, that, by a careful scrutiny of the record and fitness reports, one of the ten be selected for assignment to engineering duty.

"That officers so selected shall be given a course in higher marine engineering for at least one year at some school of engineering of reputation.

"That any officer of the line may immediately request permanent assignment to engineering duty.

"The final result of the foregoing plan would give a body of engineering specialists in the line of the Navy of about the following numbers and ranks:

Rear Admirals,		2
Captains,		7
Commanders,		11
Lieutenant Commanders,	29	62
Lieutenants,	33	
		82

"Of this number, 62—the lieutenant commanders and lieutenants—would be available for sea duty, say 30 at sea at any one time. This would give a sufficient number in each fleet to have a thoroughly competent engineer as chief engineer of each of the larger vessels, and a sufficient number to enable the commander-in-chief at all times to have available officers qualified to act in any case in which expert engineering

knowledge is necessary. These officers would have among their assistants the younger officers of the line acquiring experience, among whom would eventually be found those who would take up engineering permanently and become specialists themselves.

"The Bureau believes that such a plan, systematically carried out, would soon furnish the service with a body of competent engineers, and would place engineering where it properly belongs, in the line of the Navy.

"So much has been written in the public press advocating the establishment of a separate corps of engineers, similar to the one abolished by the personnel act, that it is deemed advisable to state the views of the Bureau upon that question.

"The Bureau is opposed to the formation of a separate corps of engineers in the Navy for the following reasons:

"1. Engineering, as the means of propulsion of ships, logically belong s to the line.

"2. Marine engineering of today demands for its votaries as high rank and as great consideration as that of the most favored branch of naval science; consequently a corps of such officers would require a certain number of positions of high rank in order to insure a proper flow of promotion, and there are not enough such positions of sufficient dignity for high rank to render the formation of such a corps justifiable.

"3. The engineer force of a modern, high-powered ship of war is a large proportion of the entire crew of such a vessel, and it is contrary to the ethics of military discipline that so many of the crew should be under the orders and direction of two separate and distinct bodies of officers.

"4. There is a widespread prejudice throughout the service against the formation of a separate corps of engineering specialists, which prejudice cannot be ignored.

"5. The controversies and jealousies incident to two bodies of officers performing duties of which the line of demarcation is very vague, so happily removed from the service by the amalgamation feature of the personnel bill, would be restored.

"6. The efficiency of a separate corps would be no greater,

if as great, as that by the proposed plan, based upon the principle that engineering belongs to the line."

Another plan, for providing officers for engineering work on shore, quite different from that recommended by Admiral Rae, was submitted to Congress by the Secretary of the Navy. The recommendations of the Secretary were embodied in a bill which provided for establishing a corps of marine engineers for shore duty only, to be recruited from graduates of technical schools. This new corps of officers was to perform the duties of designing, inspecting, constructing, overhauling and repairing naval machinery on shore, which work is now being done by line officers under the direction of the Bureau of Steam Engineering.

The above mentioned recommendations show that diversity of opinion on this subject exists even in the highest authoritative places in the Navy.

During the last two years a very voluminous discussion of engineering matters has been going on in the service papers, engineering magazines and the daily press. One very peculiar feature of this discussion is that a great many of the most critical attacks and arguments for various remedies are written by persons not in the Navy, and who, for this reason, are unfamiliar with the detail, the present status or the conditions of naval engineering. Many other arguments are also advanced by persons who are in the Navy but who have not been closely associated with engineering matters. The Navy now being so vast and complicated a concern, it is an error to suppose that an individual connected with it could be so conversant with all its details as to be an authority on all naval subjects. Therefore, the discussions whose arguments should carry the most weight are those written by men who, by reason of actual engineering experience or close association with naval engineering matters, are qualified to give an adequate and proper judgment. The following is a list of the most important discussions of this character written during the last few years:

Lieut. E. L. Beach, U. S. Naval Institute, September, 1902,

ex-engineer officer, who, since the passage of the personnel law, has served largely in line duties.

Prof. Ira Hollis, Address to Naval War College, reprinted in JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS, August, 1903; former engineer officer, resigned from Navy, now professor of engineering at Harvard University.

Lieut. U. T. Holmes, JOURNAL OF THE SOCIETY OF NAVAL ENGINEERS, ex-engineer officer, who, since the passage of the personnel law, has served in both line and engineering duty.

Lieut. Comdr. R. Chandler, U. S. Naval Institute, December, 1905, line officer not ex-engineer, who, though not having performed engineering duty on a large vessel, has had considerable engineering experience on torpedo boats and destroyers.

Report of the Chief of Bureau of Steam Engineering, 1904 and 1905, official report of recommendations for engineering matters in the Navy. Rear Admiral Rae is a member of the first class of engineers that had a course at the Naval Academy.

By reason of actual experience the above writers may be supposed to be familiar with engineering needs.

The following is a copy of a comment written to the editor of the "Army and Navy Journal," probably by a warrant machinist in the Navy. This comment would show the general view of the warrant machinists, and this view also is based on actual experience.

"TO THE EDITOR OF THE ARMY AND NAVY JOURNAL:

"It is unnecessary to recapitulate the conditions in the Navy regarding trained engineer officers, for they are well known. But all the plans for producing "sea-going" engineers will give no tangible results for a couple of years at least, and meanwhile our costly fleet is deteriorating through improper care, and the department chiefs are hampered by lack of officers. Warrant machinists are attached to the larger vessels and do good work as assistants to the senior

engineering officer; but what of the smaller ships which have no warrant machinist or experienced engineer officer? These ships are frequently kept on the most wearing duty for a ship's machinery, station duty at out-of-the-way points, far from a base of supplies and repair facilities.

"The writer spent his first year in the service as an enlisted man, only six years ago, on a gunboat having engines and auxiliaries aggregating 1,400 H.P., which carried no engineer, only a line officer detailed to the duty; yet the vessel was kept on station duty in the southern Philippines for thirteen months without a visit to any port which had machine-shop facilities. Without disrespect to the able officers who, during that time, had charge of the engineer's department of the vessel, the estimate of time and money necessary to put the ship in condition when she finally returned to Cavite, proves conclusively the expensiveness of the present method, without quoting later and more widely known cases.

"There is no doubt that, in case of war, trained marine engineers would be commissioned, after satisfactory examination, to supply the need of the service for men to get the most out of the complicated system of motive power and auxiliaries upon which a modern warship depends for its usefulness as a weapon. This course was pursued in 1898; it was considered necessary then, when the service had an Engineer Corps, and it would undoubtedly be considered so now under similar circumstances—war, actual or imminent. The President has repeatedly said that a Navy, to be a good investment, from a purely financial standpoint, if from no other, must be efficient.

"The auxiliary machinery of a naval vessel is of a quantity and type that is not found on merchant vessels. It is the auxiliary machinery which needs the most care in ordinary cruising, and upon which many of the weapons of the vessel depend for their usefulness in time of action; so that, while an engineer commissioned from the merchant service, without previous naval experience, may do very well toward maintaining, in time of war, the motive power, and obtaining from

it a high degree of efficiency, he will be hampered by his lack of acquaintance with the complicated auxiliaries, and, if they have been previously neglected, the result will be a serious impairment of the efficiency of the fighting machine as a whole.

"This seems to lead conclusively to the necessity of having men who are experienced engineers in charge of the steam-engineering department of naval vessels in times of peace, to maintain the machinery in condition to answer the extreme demands of war time. It is pretty generally conceded in private life that a man, equally skilled in two or more kinds of work, does best, and is most efficient in that work which is most congenial, for which he has the most natural aptitude. Is it not, then, too much to expect that the Annapolis graduate, who, under the best existing or proposed regulations, takes up engineering duty for a time, will regard it as anything more than an incidental tour of duty, on a par with the duties of navigator, ordnance officer or even a watch and division officer? He will be an exceptionally conscientious young man if he tries to do more than keep his department clean and 'keep things going,' unless he naturally prefers the mechanical branch, in which case he will later be a good engineer spoiled to make an indifferent watch officer. The present and proposed regulations throw the intimate knowledge of the machinery on the warrant machinists, who are doing the work formerly done by the assistant, and in some cases passed assistant engineers, previous to 1899, with practically no prospect of promotion or adequate increase of pay, such as the junior officers of the former Engineer Corps had before them.

"True, at present a warrant machinist may take the examination for ensign, but in order to do so he (presumably an engineer by profession) must 'bone' navigation, ordnance, seamanship (including sail drill!), military law, etc., and if he is successful, under present regulations, he has no surety of being assigned to engineering duty only. Under existing conditions, the warrant machinists, who are frequently the

only officers connected with the Engineer's Department on the ship acquainted with the defects and needs of the machinery, have neither the authority nor the incentive to maintain the department in the condition in which it should be; nor should they be expected to take the place of the old Engineer Corps afloat, without better prospects than they have at present.

"Why not, then, extend contemplated legislation to allow the immediate commissioning of engineers to rank and duty under practically the same conditions as those under which the senior part of the old Engineer Corps was assimilated into the line? The candidates for examination to be drawn from civil life, from commissioned officers of the Service who prefer and are qualified for engineering duty, and from the warrant machinists.

"Let the examination be as thorough as may seem advisable to the Department, so long as the requirements are in reason, I make no doubt some of the warrant machinists will try for it. Of those who try, some may succeed, and then, however small the number of successful ones, the Department will have available just that number of officers who are competent for senior engineer's duty. If this number, with that of Annapolis graduates who prefer engineering duty, is not sufficient to fill the present need, open the examination to graduates of technical schools from civil life; but let the Department first be sure that a way to promotion is open to every officer in the service who is an engineer at heart.

"ENGINEER."

It is thus natural to conclude that the persons who would really be thoroughly familar with the deficiencies of the present conditions, the manner of properly providing for them, and who would also view these conditions from a military standpoint, are the commissioned officers in the Navy who are now, and have been, actually carrying on the engineering work of the Navy at sea and on shore. Officers who have done both line and engineering duties ashore and

afloat will be best qualified to judge the subject from all points of view.

The Bureau of Steam Engineering is the representative of the engineering personnel in the Navy Department, and it is the natural and logical thing to suppose that the chief of this bureau should be in the most favorable position to know the real needs of naval engineering.

If the question of the efficiency of naval engineering is to be dealt with, and a real remedy to defects applied by Congress in the shape of laws that will provide for wants now present and those coming in the near future, it is necessary to inquire into the actual conditions, and then to indicate the nature of any remedial legislation. The question then arises, Who is qualified to make pertinent recommendations concerning these matters?

It is not the retired or ex-engineer officer who has left the service years ago, and who very often does not realize the tremendous changes that have taken place, who is qualified.

It is not the line officer of high rank who has not had engineering experience or more than a superficial engineering education.

It is not the civilian who, though he may be most learned and perhaps a better engineer than any in the Navy, has never served on board a naval vessel, and knows nothing of naval life.

What is needed is a deep and intimate knowledge, based on actual experience, of the scope and character of the work, its present condition, and the effect upon it of any of the remedies that may be applied. The subject must be treated both from a military and an engineering point of view. Therefore the opinions of those who are doing the engineering work of the Navy are the ones that should be the most heeded.

The recommendations of the Chief of the Bureau of Steam Engineering, Rear Admiral Geo. W. Melville, for the years 1900, 1901, 1902, are as follows:

"PERSONNEL.

"Another year of experience under the provisions of the 'personnel bill' finds the status of steam-engineering interests in the Navy even less fully protected, and the number and condition of the force for their control even less satisfactory than when I made my last annual report.

"The magnitude of the work under this Bureau has rapidly increased with the additional ships in commission and the new ships building, while there has been a further decrease in the number of skilled officers available for supervising this work and but few signs of speedy replacement.

"I am fully aware of the futility and folly of decrying legislation simply because the desired results therefrom do not promptly materialize, but surely time enough has now elapsed since the enactment of the reorganization scheme to make criticism of its effects upon the Navy both proper and important.

"To any close observer it is convincingly evident that either the scheme was a mistake, or that the proper course has not been taken to carry out its intent.

"I am free to acknowledge that the events of the past year have brought only discouragement to those most deeply interested in a successful outcome of this new law, but I am equally candid in the belief that the cause of this discouragement lies not in the scheme itself, but in a lack of full appreciation, on the part of the Department, of the urgency of the need for haste, not only in providing the fullest opportunity for the acquirement of practical engineering knowledge on the part of the younger officers of the former line, but in enforcing their embracement of this opportunity in the most effective manner by Department orders. It will not do to depend upon unaided individual enthusiasm or details occasioned by the necessities of particular ships. Such a course merely temporizes with the present needs, fails in any rational degree to increase the force of naval engineers (even should it suffice to replace the annual loss), and is hopelessly ineffective to secure the most desirable results in the shape of a speedy

acquirement of general knowledge of engineering on the part of the new line as a whole.

"There is an immediate and constantly increasing demand for more expert engineer officers with which to protect the interests of the Government efficiently. This demand can only be met by assigning at once, both ashore and afloat—and in as great numbers as possible consistent with absolutely necessary other duties—the younger line officers as understudies and assistants to the experienced engineers now in charge of engineering work. In no other way can the wished-for result be quickly obtained. With a full opportunity provided I am confident there will be no lack of interest or energetic application on the part of the officers detailed.

"In a number of cases former line officers have had charge of the machinery of vessels during the past year, and while, in some instances, owing to lack of experience, their control has not been marked by all desirable efficiency, in no instance has there been evidenced any carelessness or lack of close attention to the work. On the contrary their devotion to the new duty has clearly been indicated.

"With steam engineering as a line duty this is pleasing to those who formerly had its entire control, and whose greatest fear might naturally be supposed to be that no efficient engineer officers would succeed them, and that the machinery department of ships would eventually be controlled by men of a more purely practical education (machinist) incapable of maintaining that constant stress toward increased efficiency found so needful to advance or of retaining the proud position of steam engineering of the United States Navy at the head of the marine world.

"In my last annual report I endeavored to express the unsatisfactory conditions clearly, but after the lapse of another year a review of these conditions, with additional experiences, is necessary.

"First, there are available over one hundred less engineer officers than just prior to the personnel act, and at which former time I had good cause to ask for an increase in the full number then on the list.

"With this great decrease in numbers came an increase in work, making it a necessity to curtail the usual and needed allowance of engineer officers for ships until the largest could have but one, and the colliers and smaller ships often none. To the latter were assigned, in most cases, former line officers as heads of the steam-engineering department, these depending principally upon the machinists for expert directions. That many casualties have not resulted is not, however, due to the propriety and efficiency of this arrangement, nor does it indicate a safe and commendable condition, for it has only been by dint of the most anxious and continuous care on the part of the depleted force that mishaps and breakdowns have been infrequent. In other words, a state of tension has existed and now exists under which it is neither wise nor safe to continue a day, as it is sapping the energy of good men. Instead of building up a personnel for the day of need, stronger than necessary for the time of peace, the engineer officers and men are kept at the point of elastic limit, and a new war today could not fail to develop a large list of physical incapables in the engineering branch the moment the additional burden was put upon them. True, we could call upon the civilian expert for help, and no doubt secure many good men; but how foolish to deliberately lean on this uncertainty when it is possible to school our own intelligent and devoted officers to a degree of satisfactory efficiency. That this schooling will eventually be accomplished I still believe; but my earnest request is for a greater effort to hasten it in order that no day of need will find us sadly wanting. I urge you to decided steps toward this object, pointing again to the fact that, at the present rate, new expert engineers are not being made in any rational proportion whatever to the displacement of the old ones from the active list, if indeed they are being made at all.

"You are fully cognizant of the intricacy and extent of the engineering department of a large ship. That of a smaller one bears the same importance and carries the same danger for the inexperienced. You can, therefore, judge how impos-

sible it is to create in a few months expert engineers from even the most intelligent officers unused theretofore to machinery. Experience daily under all conditions of service alone perfects efficiency, when combined with intelligence, and it is this experience I ask shall be given now to all line officers possible, below the grade of lieutenant commander, both at sea and ashore. From the many we are sure to gather a fair proportion particularly adapted to the work and with natural proclivities toward mechanics. These will be the real additions to the engineering branch, and will increase as greater numbers come from the Academy. The others, fairly well versed in time, will fill the gaps in emergency or war, and with a universal general interest there will be no need to call for volunteers to man our ships in this department.

"Regarding the engineering departments of ships at sea in times of peace as well as war, compare for a moment the condition of a battleship depending for the full and proper operations of her motive power upon the knowledge of a single officer, the chief engineer, with that of another ship of the same class whereon any one of the line officers could, in emergency, take efficient charge of the machinery, and several indeed assume and completely fill the position of an expert in that department. The ideal condition of the latter is what we are now striving for, since engineering knowledge has been recognized as of the most vital importance in the service, and it is to the realization of this I still hopefully look, despite the many visible obstacles.

"That I should betray unusual anxiety on this question can only be through my intimate knowledge of the conditions now existing and my earnest interest in the welfare of the service. My views, I can properly say, should have more weight upon this point than the views of any other naval officer or board, as these cannot view the situation from as comprehensive a standpoint as can the Engineer-in-Chief, upon whose shoulders for years has been the special care and protection of naval engineering.

"Inattention to my recommendations or apathy regarding

the immediateness of the necessity for more active and decided measures toward securing the desired conditions can surely result in nothing but rapidly decreasing efficiency, from which it will be continually more difficult to recover, and the cost of which will be significant in enormously larger repair bills, shorter-lived machinery, and a fleet of vessels in doubtful fitness for their designed service—a Cervera fleet, with limititless men, but lacking the technical experts needed to meet the extraordinary and ever-new conditions of emergency and war.

"I regret I have failed to impress you to the point of action by my former communications. Had a series of calamitous events occurred during the past year to make graphic the insufficiency of the present force of expert engineers, I am sure potent remedial measures would have been promptly taken by the Department. But while glad indeed to have disaster averted, I can assure you that danger now exists. It lurks in the silence of seeming security, but a knowledge of its presence should increase the desire to hasten its removal. Fortune alone has postponed casualty.

"The country can safely count on the valor and fidelity of its officers and men, but fidelity and valor without knowledge of the use of the arms given them with which to do battle can avail little against an efficiently drilled foe, and will afford scarcely more than an exhibition of heroic sacrifice, as needless as it would be cruel. The arms of a battleship are her machinery and her guns, 'useless each without the other,' and strong to victory when working well together. No deep thought is necessary to understand this, in the light of late experiences. The very highest degree of excellence in both the condition and handling of each is the price of successful encounter, or at least is the expectation of the country. A ship motionless or helpless to maneuver well could never make efficient battle, be her guns never so good or her crew never so brave. To guard against this the head of the steam-engineering department must be full of resource and armed by experience and engineering ability only attained by years

of intimate association with machinery under all conditions of service. Haphazard luck may bring a ship through without this, but sane judgment would condemn dependence on simple fortune, or a failure to use every possible effort to insure a most competent management in this most important of ships' departments.

"Engineering work is as full of interest as it is of importance, and the line may well be proud to preserve the control of it. The most intelligent are eager to become experts, and with their superior advantages need no primary instruction. They do need much experience with and observation of machinery at work and under repair or construction, and it is for the Department to decide upon the quickest way by which they can obtain this, and then to afford them the fullest opportunities for doing so.

"I have already suggested to have incorporated in the Regulations the best method for the needed training at sea, i. e., by departmental order to compel all line officers below the navigators of ships to alternate in duty in the engine room and on deck, and efficiency reports to be made quarterly to note their progress and class their ability.

"My plea is for the highest efficiency; for immediate recognition of its importance as well as of its present decadence through depletion of the number of technical experts without full provision for early replacement. I hold up the warning finger and sound the note of alarm."

"NAVAL ACADEMY.

"As it is to this institution that we look for the future supply of officers and for that discipline and weeding out of the unqualified as shall insure to the country a yearly addition to this arm of the service in every way fitted to the needs, it becomes necessary to exercise the most careful supervision of the curriculum, as well as to retain the best force of instructors.

"We cannot magnify too much the importance of care in

this first course of preparation of the naval officer at the Academy, and I must ask that continued stress be laid upon the value of fundamental thoroughness in the steam-engineering instruction there given. In order to secure the desired results, all the line cadets must have the fullest primary instruction, such as will furnish a sure foundation for satisfactory future advances. In this course the natural proclivity of the individual will become apparent, and special aptitude can be encouraged, while a proper interest in the science can be inculcated in all.

"With a view of increasing the value of the practical part of the sea training of these cadets, I would suggest to the Department the advisability of utilizing a more modern vessel for the practice cruise, at least of the upper classes, instead of the small vessels now so utilized.

"It would be beneficial, indeed, to the cadets, and at the same time a means of securing valuable data for the Department, if the cruiser *Cincinnati* or *Raleigh*, after the rehabilitation now in hand is completed, be used for the practice cruise. To my mind there are very great advantages to be gained by this means; the cadets would become accustomed to handle and operate a modern type of ship, such as they will find in actual service, both as regards rig and battery, as well as machinery. In the latter department the new water-tube boilers and improvements in the engines make these vessels particularly fitted for this instruction work, and only a skeleton regular crew need be added to the force of cadets available.

"It seems to me that some of the time still devoted by the Academy cadets to seamanship, in the original sense of the term, may be wisely sacrificed to steam engineering, and that anomalous vessels for practice cruises can be safely exchanged for a modern type of war ship. Smoke stacks have replaced topsails and top hamper, and the officer of the deck finds more need of skill in quick maneuver than in handling canvas aloft.

"WARRANT MACHINISTS.

"From all reports this class of expert mechanics have given general satisfaction, and an increase in their number is recommended.

"The establishment of this new grade at the very time the Engineer Corps of the Navy was absorbed by the line and nominally abolished, gave rise to some apprehension lest those entering the service as warrant machinists might do so in the belief that they would eventually comprise the real Engineer Corps of the Navy and be advanced to commissioned grade, thus beginning anew a naval feature so recently abandoned. For the purpose of preventing such unreasonable hopes and for promoting content, I advised in my last report that clear and precise regulations for this grade should be promulgated, defining their duties and properly limiting their aspirations to a full and faithful discharge thereof.

"As to a layman the difference between a naval machinist and a naval engineer appears to lie merely in the character of the work each has to perform, it may not be amiss here to recall the real difference in order to make clear the impossibility of the advancement referred to without an actual disregard for the present attainments of the naval engineer and entire blindness to the present and future necessities of the service.

"The naval engineer of today must be one not only specially qualified by aptitude for his profession, and secure in a thorough technical education, in which the theories governing his later work are firmly implanted in his mind, but he must also have had actual practical experience in the different mechanical branches of his calling, gained in such a favored way as to give him intimate knowledge of the prevailing methods of work without inflicting that long apprenticeship which binds the ordinary mechanic who must pay for his training by his actual output, and whose future employment must greatly depend on manual skill. Thus years are saved in the progress possible, and extensive knowledge of designs, with immediate practice in the embodiment of

these in actual work, is obtained. Thence comes the experience gained on shipboard with machinery under all conditions of service, and the observations of the machinery of foreign ships and the work at shipbuilding establishments ashore. These experiences are only obtainable, in their full extent, by the naval officer, to whom every courtesy is extended by his professional brethren at home and abroad. Both his position aboard ship and his comparative freedom from confining detail work enables the naval engineer to broaden his professional education by the comparison of the designs and operation of machinery of different classes of ships. It also permits him to keep posted in advanced shop practice and in current engineering literature, thereby enabling him to keep out of the 'hide-binding' grooves worn by a narrower class. So much is necessary to continually study and apply, as to make a leading position in this profession only possible to one with exceptional opportunities and surroundings. Hence it is not lack of native ability, but environment and training, which precludes the possibility of simply advancing the machinist class to that of the efficient naval engineer.

"Some one may say, perhaps, if they are so advanced, they will then have the opportunities alluded to. But the reply to this is that they will only have the opportunities in a small part, and will be unfitted to embrace even these in full measure. The years of education and training cannot be given to this class then, nor would it be sane to think of so doing when the special class is being already trained for it in a higher degree than could be possible to extend to men in later life.

"The naval engineer is closely acquainted with the trades of the machinist, coppersmith, blacksmith, pattern maker and foundryman, and can judge of the quality of work in all these branches, and can do fair manual work at each, comparatively slow, it is true, owing to not maintaining manual dexterity. He is essentially superior as a supervisor of general engineering work to the most expert hand in any single one of these trades.

"The warrant machinist may have fine intellectual attainments and excellent technical training, but of necessity he must be an experienced practical engine driver and machinist tradesman, and must possess a knowledge of his special work only obtained by years of actual practice in it. He is not required to have a broader education or one specially fitting him for the more strictly intellectual field of the naval engineer, nor can he hope to secure their attainments while his time is fully occupied with the actual attention to and care of machinery. It might just as rationally be supposed that a warrant boatswain could properly be advanced to the grade and rank of captain in the Navy. Both are actually possible through necessary legislation, but both are equally undesirable and unnecessary. Lacking any other source, we might turn to these expedients, but after years of experience we are no longer in doubt as to the superior results gained through the special education of our commissioned officers, whereby they are given advantages absolutely priceless and beyond the reach of any other young men in the land.

"Nothing herein is a just cause for discontent in the warrant machinist class, but rather a cause of rational content in showing reason for devoting to their proper duties time which might be otherwise spent in fancies wholly unreasonable.

"I will state here that I believe there must always be a real Engineer Corps in the Navy. This will not necessarily be actually so characterized, but there is no doubt but that the paramount importance of engineering work will draw apart to itself a class of the line having the greatest love for the science, and best fitted to carry on the work of this branch. It must certainly be the leading work and its field must be extended here, as it is ashore, to the inclusion of all the items in naval architecture that are properly special items of mechanical engineering."—*Report for the year 1900.*

"PERSONNEL.

"It is because it is much more difficult to solve questions relating to the personnel than of the materiel that the problem of securing a trained and efficient organization continues

to command the thoughtful attention and study of distinguished naval authorities. This interest in the development and maintenance of an efficient and satisfactory personnel is not confined to commissioned officers of the Navy, for from many outside sources I have received important communications concerning the necessity and manner of best securing an efficient engineering personnel for the future needs of the service.

"From both within and without the service suggestions have reached me urging the imperative need for strengthening the Navy along engineering lines. It is the requirements of the future rather than the demands of the present which should be provided for. In case of present necessity there are available for immediate need a large body of young officers who have been carefully trained in the guiding principles of engineering science. As these young men have also had considerable practical experience in professional engineering work, their services are in readiness for emergency. It will not be long, however, before they will lose interest, aptitude, confidence, and even efficiency in engineering duties if they should specialize in other directions. From this and other causes engineering efficiency in the Navy is rapidly decreasing. With such a state of affairs the outlook for securing a trained engineering force for future needs can hardly be regarded as satisfactory.

"It should not, therefore, excite surprise when I unqualifiedly assert that there has been retrogression rather than an advance along engineering lines during the past two years. This fact is so well recognized that numerous critics have even gone so far as to suggest that a separate engineer corps is again a necessity, and that the time is opportune for the enactment of such legislation. Such a suggestion can not be entertained at the present time, for I believe that it only requires a more liberal and different interpretation of the personnel law to secure many of the advantages that were contemplated by its originators.

"Ever since the passage of the personnel bill I have con-

tended that the measure of success to be secured from the law would be altogether dependent upon the manner in which it was interpreted. It was certainly the expectation of the Congress, and also of the personnel board, that the status of engineering in the Navy would be advanced by this law. In fact, the controlling influence which made possible the passage of the bill was expressed by the then Assistant Secretary Roosevelt in his report to you upon the subject, when he stated that 'Every officer on a modern war vessel has to be a fighting engineer.' This statement so succinctly stated the fact that it received the widest approval as soon as it was published. The reason for its ready acceptance was because thoughtful men had for a considerable time previous recognized the present as an age of engineering. Particularly in respect to naval matters had the public at large come to the conclusion that the modern battleship is a floating fort filled with complex machines, whose efficient care and maintenance can only be intrusted to a trained mechanical force, and the best efforts of this force can only be obtained when directed by trained officers. This applies to every department of the ship, and is only more applicable to the engineer department because that department comprises not only the most important but the greatest number of mechanical appliances.

"I am simply stating a fact when I assert that the number of trained and expert engineers in the Navy is being steadily reduced. The practical working of the amalgamation scheme thus far has been, in great part, to take the junior half of the old Engineer Corps and transfer them to line duties. Individual officers of the old line have conscientiously striven to perfect themselves in engineering duties, but up to the present time no systematic measures have been taken to train officers for the engineering needs of the future.

"The work is too important and the needs of the future too great to depend upon individual effort to secure sufficiently numerous and trained officers for such duties. Herein has been the radical weakness of the system that has been pursued since the passage of the bill.

"The failure to establish systematic methods for maintaining engineering efficiency was anticipated by earnest friends of the Navy during the discussions attendant on the passage of the personnel bill. When the subject was being investigated the question was raised of how officers trained in engineering duties were to be obtained under the amalgamation scheme. The positive assurance was given that this was provided for by alternation of duty between the deck and engine room. The point was then raised, Why should it not be specifically stated in the bill that this alternation must take place? The answer to such question was that this was a detail which could best be carried out by departmental order or regulation. The sincere advocates of the measure believed that it would not be best to limit the Department by specific operation of law. As the proposition was one which had been indorsed by the Secretary, and even commended by the President, it was presumed that the whole influence of the Navy Department would be exerted in improving the status of engineering. It was certainly expected by the Naval Committees of the House and Senate that the Department by regulation would provide for the engineering needs of the future; otherwise this need would have been carefully taken into consideration in the framing of the measure.

"It may be urged that the work of the Navy has greatly increased since the passage of the personnel bill, and that there has been an inadequate number of officers available for all kinds of duty. This is a fact; but for every three commissioned officers taken from the engine room and transferred to deck only one commissioned officer from deck has been sent below. This does not completely describe the extent of the depletion in the engine-room supervision. The officers sent from the engine rooms were transferred to the deck for permanent duty, while in most cases the junior officers transferred from the deck have only done engine-room duty for short periods. In explanation it has been stated that 100 warrant machinists have been appointed and detailed for engine-room duty. It must be remembered that all these warrant machin-

ists came from the enlisted force of the engine rooms and had very little experience in handling large bodies of men. Without detracting, therefore, from the merits and capabilities of the warrant machinists, they are not altogether fitted by previous training or experience to take charge of an important department of the ship. Their successors, in many instances, were petty officers whose experience at sea was very limited. The gain in the engine rooms from this source has been more apparent than real. If, however, warrant machinists are competent for such duty, it may be pertinent to inquire why the boatswains and gunners, who are also warrant officers, are not equally competent to carry on the routine deck duty. Such an arrangement would permit some of the junior officers of the line to receive engineering instruction, even if it were not deemed desirable that they should render service beneath the protective deck. In the British service boatswains and gunners carry on such deck duty on small ships, and it is to be presumed that our warrant officers would also be competent for the task if such assignments were made.

"As a result of this inadequate supervision in the engine rooms there has been a perceptible decrease in the efficiency of the machinery and a progressive increase in the cost of repairs. Definite data upon this question is difficult to secure, since this retrogression is progressive in character, and the full extent of the evil cannot be determined without searching investigation. The condition of the machinery of the torpedo-boat flotilla shows the trend of affairs.

"During the past year the disablement of torpedo boats has been of such frequent occurrence that the majority of the boats have been under repair a great part of the time. Many of these mishaps are serious in character, and the present condition of the flotilla affords an incontrovertible argument in favor of the proposition that practical engineering ability of high order is required for their successful care and operation. In my opinion the machinery of the torpedo-boat craft would not be in its present deplorable condition if engineer officers of experience had been detailed for supervisory duty in connection with the boats.

"It is strikingly significant that the decrease in machinery efficiency has been most marked in the case of the torpedo boats. With this type of craft it has been attempted to practically maintain the machinery in operation without the supervision of trained engineer officers. With such a system in operation it is not surprising that inefficiency should be the rule. Upon official trials the builders of such boats find it necessary to fill the engine rooms with supervising engineers of ability and experience, who command high salaries. After such boats are turned over to the Government it cannot be expected that an insufficient and unskilled force will be capable of operating them. The depreciation of the boats will take place at a rapid rate if either an inadequate or inefficient personnel is to be intrusted with their care and maintenance.

"That efficiency beneath the protective deck is no less important in naval warfare than efficiency above it cannot be doubted. The boiler plant is the heart of the vessel, and any weakness in that direction will be followed by general decline everywhere else. The difference between an efficient and inefficient force on board a war ship was shown at the battle of Santiago. The crowning act of that victory was the overtaking of the *Colon* by the *Oregon*. In this chase a battleship of 16 knots speed, manned by an efficient engine-room force, overtook a 20-knot armored cruiser whose motive power was inefficiently handled, since only about one-half the boiler power was developed on board the *Colon* that could have been secured by a skilled force of mechanics and firemen directed by a trained and educated complement of engineer officers.

"The Bureau has reason to eventually expect efficient service from the young line officers sent to engineering duty if such junior officers are made to understand that promotion only awaits those who qualify in this direction. The greatest good that must come from such details will be manifest in the future.

"It cannot be expected that immediate results will be se-

cured from this change in the future engineering training of the naval personnel. Satisfactory progress can only be secured by development. The experience of the cadet engineer system, whose abolishment cannot be too deeply regretted, showed that a perfected system of training engineer officers could only be secured by progressive experience and observation. Although the system was established at the Naval Academy in 1866, it was fifteen years from that time before a satisfactory course of instruction had been outlined that was in keeping with the needs of the service. It will require time, also, to perfect the present system.

"As the paramount purpose of these details must be to secure an engineering personnel for the future, I strongly advise that a large contingent of the junior officers be sent to the various navy yards and to other stations where engineering instructions and experience can be secured.

"These junior officers should be detailed for engineering work exclusively. If additional duty is assigned by other Bureaus, it cannot be expected that competent officers for engineering work can be adequately trained. This is not a question of specializing along engineering lines. It is rather a question of preventing inefficiency and demoralization existing in the future. Those undertaking this work must be impressed with the fact that there are unpleasant as well as attractive features in qualifying along every line of work. Any system of training which will permit the unattractive and difficult features to be avoided will make for future inefficiency.

"When the personnel law went into effect we had an engineering corps that was recognized as the equal, if not the superior, of that possessed by any other naval power. This efficiency was secured because the junior officers of the old Engineer Corps had been taught the lesson that to attain success much disagreeable work had to be done and many unpleasant duties performed. Those who are to succeed to the duties of the old engineer officers must be taught the same lesson of interesting themselves in the difficult as well as the

attractive work of the profession. The deep-seated prejudice that existed in the Navy against engineering duties has not altogether been eradicated, and from this cause it will be a difficult matter to create the interest and enthusiasm in this work that can be secured from more congenial and conspicuous assignments. It may not require much persuasion to induce many junior officers to acquire a superficial knowledge of engineering principles. It will need determined action, however, to compel a number sufficient for the engineering needs of the future to qualify to a degree that will make them proficiently capable of performing this important duty.

"The success achieved in the past cannot be repeated unless the same pride and interest in engineering work is taken by those detailed in the future to this duty. The necessity for looking ahead being recognized, the practical problem arises as to what details of policy are essential for such success.

"It has been said that the exposition of a military weakness can only be justified by suggesting remedial measures. In order to improve existing conditions, as well as to provide for engineering necessities of the future, the following recommendations are urged:

"1. That the policy lately inaugurated of detailing junior officers of the line exclusively to engineering duties be greatly extended.

"2. That a post-graduate course of instruction in marine engineering and design be established at the Naval Academy for those junior officers of the line who desire to familiarize themselves with marine engineering.

"3. That at least two war vessels be used in part for the general training of firemen.

"In the British Navy the training of stokers is systematically carried on in the cruisers *Northumberland*, *Nelson* and *Bellerophon*, vessels of 10,000, 7,600 and 7,500 tons, respectively. In these ships the stoker is taught that he has not only hands to use but a mind to employ. After a course of instruction the recruit has a better chance of becoming for

naval purposes not only a handy man but a reasoning creature.

"Such an eminent authority as Lord Brassey recommends that the modern armored cruisers *Powerful* and *Terrible*, ships of 14,000 tons displacement and 25,000 horsepower, be employed for the special training of the engine-room complements of British war ships.

"Fighting ships are even looked upon by the British Admiralty as desirable for the training of sailors. It has been officially announced by Lord Selborne that the squadron of training ships will not be resuscitated. Instead of developing the sailor lads on the royal yards it is proposed that they be sent to sea in fighting cruisers. This significant action by the British Admiralty shows the trend toward mechanical training for the entire ship's force.

"4. That several torpedo boats be kept in commission for the training and instruction of the machinists and water tenders of the torpedo-boat service.

"5. An urgent necessity has arisen for the training for naval duties of the youthful and inexperienced machinists enlisted in inland cities. These young men can be induced to seek a life career in the Navy if some substantial recognition is accorded faithful, efficient and continuous performance of duty. The number of chief machinists now in the Navy is simply inadequate for existing needs, and a sufficient complement can only be secured by giving the machinists, second class, a systematic and thorough course of instruction so as to make them familiar with the care, operation and repair of the various auxiliaries used in the naval service. These auxiliaries include capstan, blower and winch engines; evaporators and distillers; refrigerating, hydraulic and pneumatic machinery; also the simple forms of electric motors. These machinists should be instructed as to the manner of making all kinds of joints used for high-pressure purposes, the method of packing various forms of stuffing-boxes, and, in general, the manifold duties that must be performed in the engine department of a modern war ship.

"It would be extremely advisable to send all machinists, second class, to a navy yard for practical work on ships under repair for several months. The experience and knowledge that they would gain from this experience would make them more efficient for duty on board ship, and the Navy would be the gainer from having such men trained, in great part, at a navy yard where the diversity of work on repairs would develop all who had an aptitude for a naval career. If such a course of instruction is provided, it can be confidently predicted that the corps of warrant machinists can be recruited from this source alone.

"As it is not probable that all the deserving machinists can from henceforth expect to secure warrant rank, I would urgently recommend that all machinists among the enlisted force who have served honorably for a period of twenty years be only assigned to duty at navy yards. There is much duty that these men could do at the naval stations, such as running tugs, taking charge of the steam fire engines, looking out for the various boiler plants, and taking charge of the machinery of the ships in ordinary.

"Under existing conditions machinists only remain long enough in the service to fit themselves for taking positions in the merchant marine. They are lost to the naval service just when they are most efficient, and such a deplorable state of affairs should be remedied, if possible. I believe that the Department has only to offer some substantial reward in the form of permanent duty at a navy yard to induce many machinists to render twenty years' faithful service, and to look upon the Navy as a life career, and not as a temporary vocation which affords an opportunity for travel and sight-seeing.

"6. That the warrant machinists be placed upon the same footing as regards pay and rank and emoluments as given other warrant officers. In some respects the warrant machinists are discriminated against, and so long as this distinction exists they will have a grievance which must interfere with the efficiency of the engine-room force. Every avenue to

promotion and increase of pay that is accorded other warrant officers should be given warrant machinists. The responsibility and character of the duty that rests upon this class of officers is as important as that devolving upon sailmakers, carpenters, boatswains and gunners, and the opportunity for advancement should be equally as great.

"7. That a special rate of pay be allowed those petty officers in the engine department who qualify as water tenders of torpedo boats. Such a substantial reward is given those who qualify in certain deck duties, and the same inducement should be held out to the leading petty officers doing duty beneath the protective deck.

"In connection with this subject of personnel there are features whose importance should be impressed upon the service at large. It is a certainty that the number of officers, doing engineering duty only, will diminish much more rapidly than is anticipated, and probably much sooner than is desired. By reason of the present interpretation of the personnel law the inducements for such officers to continue this work are very few. As attractive retirement features of the personnel law will soon be applicable to the majority of such engineer officers, it can be expected that the opportunities offered will be taken advantage of by many who are now doing engineering duty only.

"It would also be well for thoughtful naval officers to compare our work in training an engineering personnel for the future with efforts that are being made by other naval powers. Is the engineering course at Annapolis comparable with that given the British engineering cadets at Keyham? Are we in advance or behind other nations in systematically training the petty officers and stokers of the engine-room force?

"The war ships of the future must be provided with a strong complement of commissioned engineer officers. The number and character of the enlisted force working beneath the protective deck, as well as the extent and complexity of the motive power, demand and require that there be detailed,

for this supervision, a complement of educated officers possessing ability and high character. Either the junior officers of the line must be compelled to take up this work, or public sentiment will demand that the warrant officers be advanced to official positions commensurate with duties imposed upon them."—*Report for the year 1901.*

"PERSONNEL.

"It is now five years since the substantial features of the naval personnel bill were agreed upon by representative officers of the naval service and approved by the executive administrators of the Navy Department. Fortunately for the interests of the Navy, a period of fifteen months elapsed from the time the bill was introduced in the Congress until it became a law. During the intervening time the subject was studied by many thoughtful officers, as well as by the members of both Naval Committees. This reflection and investigation caused the merits and weaknesses of the measure to be pointed out and permitted the friends of the bill to arouse public sentiment in favor of the adoption of a proposition that had been carefully considered by officers of various grades and corps, and which was the practical outcome of twenty years' study of the subject.

"Three and one-half years have elapsed since the bill was made a law. After an experience of that length of time, it would seem as if a decision should have been reached as to the ultimate success of the project. It is simply stating a fact when it is asserted that one-half of the line officers on the active list of the Navy have yet to be convinced of the utility of amalgamating the duties of the deck and engineer officers. As for the retired officers, it is the exception to find those who have any sympathy with the scheme, or who do not predict an inefficient naval service as a result of the experiment.

"A careful perusal of the naval periodicals of America and Europe, as well as extended correspondence and personal interviews with hundreds of persons interested in the question, convinces me that the best friends of the Navy without the

service, as well as the Admiralty officials abroad, are still amazed at the experiment that we have undertaken. In fact, they are more doubtful than they ever were before of the ultimate success of the scheme. There is an old adage which states that the looker on sometimes sees more of the game than the players. This truth should be kept in mind in giving weight to the opinion of retired naval officers of our own service, of friends without the organization and of thoughtful foreign experts as to the beneficial operation of the law.

"It is but fair to state, however, that many officers in our own service, who should have the best means of observing the result of the experiment, are convinced that the passage of the law was in the line of naval development and advancement. But even some of these officers have admitted that more substantial results ought to be apparent by reason of the favorable conditions under which the law went into effect and in view of the period of time that the experiment has been in operation.

"While the amalgamation of the duties of the line and engineer corps was undoubtedly the essential feature of the personnel law, there were thoughtful officers who were more interested in the passage of the bill by reason of the fact that the measure contained provisions whereby voluntary and compulsory retirement was secured, thus insuring a healthy flow of promotion from the various grades. For over fifty years naval experts had been urging the enactment of legislation which would make it possible for officers to secure command and flag rank at a period of life when they were best able to take up exacting and important duties. Where seniority promotion alone prevailed, the mental and physical vigor of some officers had often become impaired by the time they reached flag and even command rank, and it was to remedy this weakness that it was deemed expedient to follow the experience of foreign powers by using radical measures to insure a regular flow of promotion.

"It should also be kept in mind that nearly every officer in the naval service either secured promotion or received increased pay as a result of the personnel law. The officers of

the Navy had been underpaid for many years, and any measure which tended to correct this injustice naturally commended itself to the favor of the service at large. This was no small factor in overcoming opposition that would otherwise have asserted itself, and the far-reaching effect of incorporating the amendments relating to pay and retirement cannot be overestimated.

"When the bill was presented to the Congress, its provisions were carefully studied by all interested in naval affairs. While fully cognizant of the necessity of enacting into law the retirement features of the measure, the members of the Naval Committees thoroughly realized that the question of amalgamation was the most important in the bill. This particular feature, therefore, received careful consideration, and only a campaign of education brought a majority of the committee to its support. It seemed apparent to both Naval Committees that the proposition conflicted with the tendency of the age toward specialization, and that the doom of engineering in the Navy was inevitable unless compulsory means were taken to compel officers to train in that direction.

"The measure was regarded by many as ill-advised because the bill did not explicitly make provision for compelling the performance of engineering duty. This objection appealed so strongly to certain members that the passage of the bill was imperiled by the insistence upon the part of some friends of engineering that special sections should be incorporated whereby this defect could be avoided. In answer to this contention it was shown that it would be extremely difficult to frame a law which would secure the desired result, since experience and observation upon the part of conscientious naval officers was absolutely essential before hard and fast rules could be made. It was the general opinion that the question of regulating the performance of engineering duty was one of administrative detail which the Bureau of Navigation could be depended upon to carry out, since the importance of engineering had been recognized by the Department in many official communications to the Congress. The Naval Com-

mittees were thus unofficially assured that departmental regulations and orders would be issued to overcome this anticipated weakness. It was also understood that when time and experience justified changes the Department would promulgate orders and regulations upon the subject.

"It was rather a revolution than progression in naval development which occurred when the Congress enacted a law whereby every naval officer of the line had in the future to become a fighting engineer. This epigram of President Roosevelt aroused earnest discussion, and caused the question of naval matériel to be subordinated to that of the personnel. It declared for a policy which amazed even the British Admiralty. The opinion of continental powers can possibly be gathered from the declaration of a naval attaché, who informed me that either the European navies had not an organization adapted to a modern warship, or else that the American service had committed itself to an error of policy which would require twenty years to correct. As there have been other American innovations which have amazed Europe and which have proved to be founded upon correct principles, the opinion of the continental powers as regards the personnel law may be equally erroneous. But where there is a radical difference in the training of the personnel, it is certain that there must be a great difference in the efficiency and strength of the several navies, and too much thought cannot be given to the question as to whether or not our present policy is the correct one. While it has not been difficult to convince naval experts that the principle of amalgamation is correct, but few converts have been found outside the United States to the belief that the principle can be practically applied except through progressive development. The naval authorities in Europe are thus more than skeptical as to the utility of the measure, since they assert that it conflicts with the customs and traditions of the Navy as well as with the tendency of the times.

"In measuring the results secured, it should be remembered that when the personnel law went into effect there were in the engine rooms of our war ships, in addition to an efficient

commissioned Engineer Corps, an exceedingly well-trained and intelligent complement of skilled machinists. These men had been drilled by engineer graduates of the Naval Academy, and a state of efficiency had been reached in our engine rooms that had not been surpassed by that of any other service. In the competitive examination that was held for the position of warrant machinist just after the close of the Spanish-American war the character and ability of the machinists of the Navy were put to an actual test. Almost without exception the successful competitors came from the naval ships. These men were not only well acquainted with the machinery of our war vessels, but they had been taught by example and precept the necessity of keeping every machine in a high state of efficiency. They had witnessed the courage and devotion to duty upon the part of the engineer commissioned officers, and thus had not only been made to implicitly obey, but they had been taught the necessity of efficiently directing affairs, so that when promotion was tendered such enlisted men they were competent to perform higher duties that could not be safely intrusted to those without naval experience.

"Two-thirds of these warrant officers have now been continuously at sea since the passage of the personnel bill. In many instances these men had over ten years' previous service and in some cases as much as twenty years' training in the Navy. As all had to serve a year on probation before securing warrant rank, and as a majority anticipated securing a shore assignment at the end of their cruise, these incentives have been no small factors in keeping warrant machinists up to their work and in maintaining efficiency beneath the protective decks of our war ships.

"The fact should be thus thoroughly appreciated that as regards the efficiency of the warrant machinist those now in the service are as a rule a picked body of men, who had not only received special training, but who had considerable experience in the several types of ships to which they have been assigned. Since the demand for skilled marine engineers is

very great in the maritime marine, it will be difficult to secure warrant machinists from that source, and, therefore, the Navy will have to train this class of men. As it cannot be expected that these men will be content with less recognition and privileges than is accorded other warrant officers, the number, of necessity, must be increased.

"These officers will demand, and it would seem as if they are justly entitled to receive, the same consideration as regards shore duty that is accorded boatswains, gunners, carpenters and sailmakers. The Department, therefore, can not expect to keep these men continuously at sea. A reasonable amount of shore duty will have to be given them or the Navy will lose the services of the elect. The personal inquiries that have been made at this Bureau as to the capabilities of the best of the warrant machinists show that the shipbuilding firms intend to draw upon the best of these men and that salaries will be offered which will induce the most efficient to leave the naval service in case these machinists are not to be put upon equality with the other warrant officers as regards shore assignments.

"While the warrant machinists have had shop training and experience at sea, it can not be expected that they possess the necessary scientific training to enable them to take up the most important duties that were performed in the past by the commissioned officers of the old Engineer Corps. These men may have the skill to adjust bearings, set a valve, replace a water tube in a modern marine boiler, overhaul a pump, and possess the requisite knowledge for operating machinery with which they are familiar, but in matters of organization the services of more highly trained men are needed. There are great laws of mechanics, physics, chemistry and thermodynamics which must be put to practical application by the chief engineer of a war ship. It is a thorough grasp of these principles, combined with practical sea experience and power of observation and study, which makes the competent marine engineer.

"It is not my desire to disparage the work of the warrant

machinists. These men are rendering useful and efficient service, and provision should be made whereby the elect might quickly secure commissions in the Navy. It is my great desire to encourage them and advance their material interests, but as a rule this class of officers can no more do the work of trained and educated engineers than can carpenters take up the duty of naval constructors, gunners assume the responsibilities devolving upon ordnance experts, or boatswains attain the skill and executive ability of skilled sea commanders.

"The belief that warrant machinists, if competent to take charge of the machinery of a modern war ship, will rest content with either the pay or position now accorded them is simply to invite another half century of internal strife in the Navy. It is nothing more than an attempt to revive conditions that existed when the screw propeller was first used. The machinists will simply tread the path that was broken by the officers of the old Engineer Corps, and success will be achieved by them in a short time, for the engineers taught them the lesson that great reforms can only be effected in a military service from pressure without rather than from efforts within the organization.

"It has been because the belief prevails in some quarters that the experience of a single cruise in the engine room will fit junior officers for the duty of a chief engineer, and that the practical duties at sea of the old engineer officers can be taken up by the warrant machinists, that there has been continued retrogression in the engineer efficiency of the Navy. To sustain the opinion that there has been retrogression the attention of the Department is invited to the consideration of Senate Doc. No. 175, Fifty-seventh Congress, first session, wherein the Paymaster General of the Navy, in a report in answer to a Senate resolution, forwards data as to the costs of repairs to the naval vessels. This document is substantially a financial history of the ships of the new Navy, and shows the heavy expenditures incurred in keeping the vessels in a state of efficiency. This retrogression will not cease until at

least one-fifth of the 1,800 commissioned officers, midshipmen and warrant officers are assigned to engineering duty.

"Many young line officers have shown decided aptitude for engineering work, and have been assigned to such duty. The number, however, who have specially interested themselves in the work has been too small for the best interest of the service. There have been some who have taken up the work in an amateur fashion and as a diversion. The injury to engineering efficiency from countenancing this kind of duty is very great, since it demoralizes the enlisted force in the engine and firerooms, and tends to discredit the work in the estimation of those who should be made to interest themselves in the duty.

"The principle of amalgamating the duties of the line and engineer officers is, however, in accord with the trend of modern development, and it is by reason of this fact that the proposition received the hearty and unqualified support of the engineering interests throughout the country. It was an official recognition, upon the part of the Congress, of the dignity and importance of the engineering profession. It was also an emphatic declaration on the part of the legislative assembly that an organization which was suitable for vessels of oak was not compatible for the needs of ships of steel, and that the men beneath the protected deck in the engine rooms and stokeholes were as much an integral part of the ship as the men who served and trained the guns. This legislation, however, assailed the traditions of the service, and it was not surprising that opposition developed when it was presumed that vested rights had been encroached upon. This opposition was powerless in its appeal to Congress to reject the measure. It commanded greater strength within the naval service, and it is this influence which stands in the way of a liberal and generous enforcement of the unwritten but well-understood provisions of the personnel law.

"If the law is administered with a desire to make it a success, it will, beyond a doubt, give us the most efficient Navy in the world. It must, however, be administered in a way

that will prevent junior officers from showing a decided preference for deck duty, and this result can in great part be secured by refusing to promote those who have not had actual and continuous experience in the engine room, and whose semi-annual reports as to fitness do not show that they have been zealous and proficient in the performance of engineering duty.

"It is with pleasure that I bear testimony to the fact that during the past year a more determined effort has been made to carry out the intent of the personnel law to make every officer an efficient engineer. Junior officers of the line are now assigned by departmental order to special duty as chief engineers of vessels, and thus these young men are not only made to identify themselves more closely with the work, but it is possible to hold them to a more rigid responsibility for the character of the engineering duty performed.

"It is regrettable, however, that more junior officers are not detailed for duty in the engine and firerooms, since it is as essential to provide for the needs of the future as the demands of the present. The great scarcity of officers has probably made it difficult to arrange for alternation of duty on the scale contemplated when the personnel law was passed. There has been, however, no substantial abridgment in the number of officers assigned for deck duty, and it is an undoubted fact that fewer commissioned officers are now doing engineering duty than when the law went into effect. It will be said that there are 145 warrant machinists assisting these commanding officers, but practically all these warrant machinists were in the engine rooms of our war ships when the law was passed. At that time the warrant machinists were in the Navy, but without the promotion that has since been justly given them.

"There has been no hesitancy to intrust responsible duties in the engine rooms to warrant machinists, and surely many of the boatswains and gunners are capable of performing routine duty on deck, thus permitting a considerable number of junior officers of the line to be assigned as assistant inspectors

of machinery on shore. There can be no more risk in trying the experiment of utilizing the services of boatswains and gunners as watch keepers on the bridge than in placing machinists in charge of the engine-room watch. It would appear as if the deck experiment would be the less dangerous one, since in times of emergency either the captain, executive officer or navigator is within immediate call of the officer of the deck.

"By reason of the inadequate number of officers assigned to engineering duty on shore, the interests of the service have been greatly endangered. There is not a naval station nor shipyard where more officers are not needed for engineering duty. There is now in course of construction 250,000 horsepower of boilers of the Babcock & Wilcox design, and the only officer available for this duty is a veteran of the civil war. This officer is on the retired list, having sought voluntary retirement after forty years of active service. By reason of his special aptitude for the work the Bureau has continued him on duty. The task of inspecting marine boilers, of a design that the Bureau believes may be eventually selected as the approved type for the Navy, should not be intrusted to junior officers who might be unexpectedly ordered to sea at short notice. The Bureau would be pleased, however, to have several junior line officers ordered as assistants to the senior inspector of these boilers, but such important duty cannot be assigned to juniors who have not had extended engineering experience and training.

"About 125,000 horsepower of boilers of the Niclausse design are likewise in course of construction, and only one officer is available for this work. The good of the service would demand that several junior officers be detailed as assistants to each of the engineer inspectors of these boilers. The modern naval officer cannot efficiently operate machines unless he has had some experience in superintending their construction and installation. In the effort to keep the ships going at sea important duties on shore are being slighted, and surely more officers should be detailed for this special work.

"The personnel law contemplated that officers should reach command rank before they attained the age of 45 years, and that those doing engineering duty only, when attaining the rank of commander, should not perform service at sea. This provision was founded upon the opinion that any officer of scientific training and education electing to do engineering duty only, and with twenty-five years of naval experience, could render the best service to the Navy by supervisory work on shore, since physical vigor and age were important factors in the performance of engineering duty at sea. Those officers doing engineering duty only who are now beyond that age could be best employed in the inspection work on shore, since there is an urgent demand in the various naval stations and shipyards for officers possessing this special experience and training. But some junior officer should be in training to relieve every one of these seniors.

"It is pertinent to call attention to the fact that the competition between shipbuilders for naval work is more keen than it ever was before, and that there is not the margin of profit that was obtainable in the past by the contractors. Many of the shipbuilding plants now sublet considerable of their work, and this entails more rigid inspection upon the part of the Government official. The interests of the service are not being subserved by changing the inspectors frequently, for the naval experts are pitted against highly paid specialists who are not only loyal and zealous in representing the cause of their employers, but who have an advantage over the naval officers by reason of their long assignment in connection with the work in hand.

"By reason of the inadequate number of officers employed in the inspection of naval machinery, it is certain that the ships now in course of construction will not be the equal of those built in the past so far as relates to the motive power. This opinion is based upon careful study and experience, and is meant in no manner to reflect upon the integrity of the shipbuilders. The naval specifications are much more severe than those for mercantile work, and these requirements can

only be obtained by detailing as inspectors efficient and experienced officers whose education and training at sea gives them an intimate and professional knowledge of the needs of a war ship. The shipbuilders fully recognize the fact that an efficient and conscientious naval inspector, who holds them to a rigid and yet not vexatious responsibility, is in reality of great benefit to them, for such an officer when requested to tender advice is ever ready to give information. It has been repeatedly the case that the advice of such inspector has prevented the contractors from making mistakes which would have caused financial loss and long delay to the shipbuilding firms.

"The existing policy of overloading the naval inspectors is therefore not to the permanent benefit of the contractors. While it is true that an unscrupulous firm might secure a temporary advantage, the well established and reliable companies suffer pecuniary loss by vexatious delays. As the Department calls upon such inspectors for specific duties, it is impossible for them at times not to delay the contractors by the failure to inspect completed work. It is exceedingly probable that the courts will yet be called upon to determine the responsibility of the Department in this matter. Where there is an inadequate number of inspectors there is likely to be untrustworthiness in the character of the work, delay in construction, and heavy financial loss to the builders.

"The inadequate force assigned to engineering duty in naval matters has excited comment in the engineering world. One has but to read the editorial comments of the marine engineering periodicals to note how well informed the general public is in regard to engineering conditions in the Navy. The present age being distinctively an engineering one, there are thousands of educated and scientific engineers scattered over the country who take a deep interest in the design, construction, and operation of the warship. These men are closely watching the effect of the personnel law in the passage of which the engineering profession was no small factor. Whether or not it is its prerogative, the engineering profes-

sion feels that it is specially charged to see that the motive power of the Navy is kept efficient. The events of the past have shown that the profession is not powerless to accomplish its purpose in this respect, for it will always be accorded a careful hearing by the executive head of the Navy Department and by the Congress.

"While the personnel law is correct in principle, there is a general feeling among engineers that the purpose and spirit of the measure is not being carried out. Of the 1,425 commissioned officers and midshipmen, 78 in accordance with law are doing engineering duty only. Possibly 70 other junior officers of the line are giving all or half of their time to the performance of engineering work. Not over one-eighth of the officers below the rank of commander are thus doing engineering work. One would have to possess strong imaginative powers to believe that either the present or future engineering efficiency of the Navy is being looked out for under such circumstances. While there are 145 warrant machinists for duty in the engine room there are 286 other warrant officers for deck duty.

"In the vessels of the merchant marine there are as many engineers as deck officers, and surely a proportion of four deck officers to one engine-room officer should be ample, even in a modern navy. Excluding the marine officers, who have charge of the secondary batteries on some of the large ships, there are 1,856 warrant officers, midshipmen and commissioned officers. Allowing one-fifth of this total number for engineering duty ashore and afloat, there should be at least 370 assigned to this work instead of the 300 who are now doing the duty. The request of the Bureau that such a proportion should be assigned for engineering work cannot be regarded as excessive. It is certain that there are too few now doing such duty, and the continuance of the present policy will give us a fleet of war ships whose future engineering efficiency will more resemble the defeated than the victorious squadron at the battles of Santiago and Manila.

"In making an earnest plea for the complete administra-

tion of the personnel law, no element of personal consideration has influenced my action. I am a convert to, and not an original advocate of, the idea. I am most concerned that engineering efficiency in the Navy shall not be sacrificed, and that the great fighting machines, whose motive power has been designed at this Bureau, shall not fail in the work expected of them because they are not properly cared for.

"A navy without highly-trained and technically-educated engineers is a navy that will not stand the test of battle. It is an outworn system which attempts to have the medieval traditions of the sailing age prevail on board the fighting machines of the present generation.

"The result of forty years' experience in the Navy and the warning notes sounded by hundreds of persons within and without the service compels unequivocal declarations to be made as to the condition of affairs. Although these conditions are somewhat better than they were a year ago, we are passing through a period of engineering inefficiency which is not only subjecting the nation to great expense but is inviting disaster. The present condition of affairs cannot and should not be permitted to continue. The Navy Department and the Congress may be spurred to action from strong influences without the service unless a greater proportion of the commissioned personnel is assigned to engineering duties. As the engineering profession is carefully noting existing conditions, would it not be wise to do the work of strengthening the service along engineering lines within the naval organization rather than to have the Congress again take up the matter, when the formation of a separate corps of naval engineers, endowed with military rank and authority, will not only be a possibility but a decided probability?

"It may be asked why the time has not arrived when experiments should be tried of interpreting the personnel law more in the line of engineering progress and opinion. The fact should be emphasized that those who hold to this belief do not simply criticise existing methods. Such action would be inexcusable, for no loyal and patriotic man will expose the

military weakness of his country until he has shown wherein improvement is possible. Therefore, the friends of engineering, in the belief that the law is correct in principle but maintaining that it has been construed in a manner that is not conducive either to present or future engineering efficiency, request the Department to give careful consideration to the following recommendations:

"These recommendations relate to increasing the engineering influence, efficiency and duties of the commissioned personnel; of improving the condition and efficiency of the engineers enlisted force; and of intrusting to the distinctively Engineering Bureau of the Department the design, construction, installation and operation of all machinery other than that of ordnance.

"First. The establishment at the Naval Academy of an engineering experimental laboratory. The purpose and necessity for such an institution, and its relation to the question of an efficient naval personnel is well recognized in Germany, where engineering as a profession has been accorded even a higher status than it has in America and England. The German Admiralty has such a laboratory at Charlottenburg, and it is the belief on the Continent that the advance of Germany in naval and marine development is in no small part due to the magnificent work done at this station. The value of such an engineering laboratory to the Navy and to the nation, and its far-reaching influence upon technical education at Annapolis is of such great importance that it has been particularly referred to in this and preceding annual reports.

"Second. The establishment at the Naval Academy of a postgraduate course in engineering. If technical instruction of an advanced nature should be provided at Annapolis for junior officers who have special engineering talent, the advantages would be of a three-fold nature, since the junior officers, the Naval Academy and the service at large would be benefited by the work. The junior officers would be better fitted for undertaking the more important engineering duties of the future. The Naval Academy would be brought in

closer relation with the higher technical institutions of the country, and this would give the Annapolis institution an opportunity to compare educational methods, so that, where necessary, there could be improvement effected in the character of the instruction. The service at large would be the gainer by reason of the fact that every officer who took a course in postgraduate work would be a personal factor in preventing any decrease in engineering efficiency.

"Third. The detail of a junior officer of the line as an understudy and assistant to every officer on shore doing engineering duty only. Practically the only officers detailed as inspectors of machinery and engineering material are the few officers who have elected to do engineering duty. These officers by reason of their training and extended experience are particularly well qualified for the duty assigned them, but everyone of them is overworked, and the good of the service would be subserved by detailing someone to assist them. The junior officers assigned to this work would not only render a direct service to the Department in relieving their seniors of routine duties, but these understudies would be fitted for doing all the work in the future. One of the great menaces to naval efficiency is the fact that practically no junior officers of the line are doing engineering duty on shore. There can be no more important duty within the assignment of the Department than the training of an adequate complement of junior officers so that they will be fitted to perform the distinctively engineering work of the future.

"Fourth. That the junior officers of the line, by specific orders of the Department, in connection with the warrant machinists be placed in charge of the machinery of all torpedo boats and destroyers, auxiliary vessels and yachts, gunboats and small cruisers, as well as monitors and nondescript vessels. It is simply discrediting engineering to detail an officer of twenty years' experience to take charge of machinery of a small cruiser. In several instances officers of this experience have been withdrawn from important shore duties, where the Department had great interest at stake, to perform service at

sea which ought to be done under existing conditions by junior officers of the line.

"Fifth. A general order should be issued of such emphatic nature that the junior officers of the line would thoroughly appreciate the fact that promotion would be denied those officers who had not performed duty in the engine room, or who had not sought work of this character. Such an order would prevent a preference being shown deck duty, for however unattractive the work in the engine room might be, there would be no effort to avoid it if lack of such experience interfered with promotion.

"Sixth. That in view of the urgent demand for officers, and by reason of the fact that the Naval Academy is unable to send forth a sufficient number of graduates, that a law be enacted empowering the Secretary of the Navy to permit graduates of the technological colleges to compete for acting commissions in the service. That the successful competitors then be ordered to the Naval Academy for a one year's course of instruction in ordnance, gunnery and navigation, and that they then be sent to sea on board a modern warship for one year for practical instruction. That those who successfully complete the course prescribed by the Navy Department, both at the Naval Academy and at sea, be then given permanent commissions in the regular service. Such a policy would give us highly desirable officers for our immediate needs. They would not have that intimate knowledge of naval customs and traditions that had been acquired by the Naval Academy graduates, but they would have a much more rounded education, since the requirements for entering the technological colleges are much higher than those for entering the Naval Academy. From this source it is possible to secure some excellent men, and a reserve of trained officers for future contingencies could be educated in this manner. Such a system of increasing the personnel would bring the service nearer the hearts of the people, for in the course of a decade the alumni associations of every great university would have some of its representatives holding commissions in the line of the Navy.

"Seventh. That one hundred more warrant machinists be appointed. There is important work on shore for this class of officers to do, and the detail of warrant machinists who have been continuously at sea for years to temporary shore assignments would not only be an incentive to keep them in the service, but it would better fit them for carrying on their duty afloat.

"Eighth. That the system of instructing machinists second class, now in operation at the New York Navy Yard, be extended so that this training might be given at every leading naval station. The success of the school at the New York Navy Yard shows a necessity for extending the work. Once let the youg mechanics of the country learn of the opportunity to receive this professional and practical instruction, and an incentive to enlistment would be created that would make good the deficiency now existing in the number of machinists requisite for the ships of the Navy. The good results of establishing this school will not only be manifest in the decreased cost of repairs to warships, but in the higher efficiency of these men when reporting on seagoing vessels.

"Ninth. That in view of the fact that the water-tube boiler must soon of a necessity be the principal type in the naval service, that the status and pay of the water tenders be increased to a degree commensurate with the importance and nature of their duties. Considering the character of the duty performed by these petty officers, the water tenders are the most inadequately recognized and poorest paid of any of the enlisted force of the Navy.

"Tenth. That the title of the Bureau of Steam Engineering be changed to that of the Bureau of Engineering, and that there be placed under its cognizance all machinery which is distinctively engineering in character, other than that of ordnance. In view of the fact that the line officers of the future must have a knowledge of mechanical, electrical, pneumatic and hydraulic engineering, there should be a bureau at the Navy Department whose province it would be to design and have control of all of the machinery of this character. It

cannot make for naval efficiency to call upon an officer to be responsible for the repair, care and operation of a mechanical contrivance without permitting such officer to determine the character and design of the appliance. There is much in the word 'engineering,' and if the naval service will ally itself with the profession at large, a moral and substantial support will be tendered the organization that will be a tower of strength in times of emergency. The amalgamation of the duties of the line and engineer officers can only be accomplished by giving engineering a status that will command the respect and esteem of everybody within the organization, and this purpose can be greatly aided by enlarging the scope and influence of the only distinctively engineering bureau that now exists by operation of law."—*Report for the year 1902.*

In order to understand more fully the needs and conditions of this question, an examination into the actual scope of naval engineering work and its present condition should be made. The work assigned to the Engineering Bureau of the Navy Department is in general terms defined in Article IX of the U. S. Naval Regulations.

"U. S. NAVY REGULATIONS.—BUREAU OF STEAM ENGINEERING.

"*Article IX.*

"1. The duties of the Bureau of Steam Engineering shall comprise all that relates to designing, building, fitting out and repairing the steam machinery used for the propulsion of naval vessels; the steam pumps, steam heaters, distilling apparatus, refrigerating apparatus, all steam connections of ships and the steam machinery necessary for actuating the apparatus by which turrets are turned; also to requiring for or manufacturing all its equipage and supplies for ships prescribed by the authorized allowance lists.

"2. It shall design the various shops at navy yards and stations where its own work is executed, so far as their internal arrangements are concerned.

"3. It shall determine upon and require for or manufacture all its machinery and tools and shall erect and repair the same. It shall require for or manufacture the stores, stationery, blank books, forms, fuel, material and all means and appliances of every kind required for its own purposes.

"4. It shall superintend all work done under it.

"5. It shall have control of the organization and muster of the employees used entirely for its own purposes.

"6. It shall estimate for and defray from its own funds the cost necessary to carry out its duties as above defined.

"7. Orders relating to Navy Yard business connected with the Bureau shall be given by the Chief of Bureau to the commandants, who shall be responsible for their execution."

On board ship the senior engineer officer is charged with the care, condition and operation of the boilers; the main engines and their dependencies; the pumping, distilling, heating and refrigerating plant; the general workshop in which machinery repairs to all parts of the ship are made; the direction of all repairs to all steam machinery, and the care of all compartments within the limits of the machinery spaces. The engineer force on some of the largest vessels consists of nearly three hundred men, and is about one-third of the crew on the large armored cruisers.

A very curious anomaly of the regulations is that such purely engineering apparatus as the steering engine, capstan engine and the dynamo plant are not under the control of the engineer officer, though he is charged with their repair at sea. As may be supposed, this very strange condition leads to considerable waste of labor and no little trouble and annoyance on account of these machines being under the divided control of several officers and bureaus. The burden of any accident or trouble, in most cases, falls upon the engineer department, which has to repair and make good any breakdown, though it has no authoritative voice as to the proper handling or caring for of the machines. When a vessel is repaired at a navy yard the engineer officer does not control or direct the repairs to these machines, for they are under the control of

another yard department than his own. This very curious condition of divided control is brought about by the fact that the steering engine and the capstan engine are under the cognizance of the Bureau of Construction and Repair, and the dynamo plant under the cognizance of the Bureau of Equipment. Much simplification of the machinery itself, and of its operation, care and management, would be secured if all engineering matters were placed under the cognizance of the engineering bureau.

The regulations now in force defining the duties of the engineer officers are as follows (extracts from U. S. Navy regulations):

"CHAPTER XIII.

"ENGINEER OFFICERS.

"650. (1) The engineering duties of the ship shall be performed by officers of the line, below the grade of commander, detailed therefor; and, during such detail, they shall be known as the engineer officers of the ship.

"(2) Officers of the line assigned to duty with the engineer force of a ship, excepting those detailed by the Department, shall continue on such duty for six months from the date of such assignment, if practicable, and shall be relieved from it at the expiration of a year. Commanding officers of the vessels will inform the Bureau of Navigation of the dates of detail and relief of all officers performing engineering duty on board ship.

"SECTION 1.—THE SENIOR ENGINEER OFFICER.

"*Duty when Fitting Out.*

"651. (1) The senior engineer officer shall be detailed as such by the Department.

"(2) He shall, upon joining a ship fitting out, make a careful examination of all parts of the steam machinery used for motive power of the ship and her boats; of steering, hydraulic accumulator and turret-turning engines, when these are worked by steam; of the ash, anchor and other hoisting en-

gines, dynamo engines, pumps, fan blowers and ventilating engines, which are worked by steam; of the steam heaters, evaporators and distilling apparatus; of the refrigerating machinery and all other machinery of whatever description operated by steam, wherever found in the ship; of all steam connections; of the boilers and coal bunkers; of all tanks, cisterns and storerooms for engineers' supplies.

"(3) He shall satisfy himself that the spare gear belonging to his department is on board, tried in place where necessary, stowed in convenient location, and that every precaution is taken to preserve it in good condition.

"(4) Should he discover any defects or deficiencies, he shall immediately make a detailed written report of the facts to the captain.

"652. (1) He shall be responsible for the preservation and efficient working of all machinery under cognizance of the Bureau of Steam Engineering; the motive engines and their dependencies, both of the ship and her boats; the steam machinery necessary in actuating the apparatus by which turrets are turned; the steam and hydraulic turret-turning engines; the steam pumps, steam heaters, steam connections and pipes, distilling apparatus, refrigerating engines, forced-draft blowers and steam fire pumps.

"(2) He shall also be responsible for the cleanliness and good condition of all bulkheads, doors, valves, pipes and machinery within the engine rooms; of the boiler rooms, shaft alleys, coal bunkers, firemen's wash rooms, engineer storerooms and work shops; of all compartments and double bottoms within the line of such bulkheads, together with those compartments and double bottoms accessible only through the engineer compartments.

"(3) He shall also be responsible for the efficiency and good condition of all valves, cocks and pipes within the engineer compartments connected with hand pumps; and he shall see that the suction and bilge wells are kept free from ashes, dirt and grease.

"653. (1) He shall make frequent inspections of the steam

machinery under the cognizance of other bureaus, and report to the captain any repairs or adjustments which, in his judgment, are necessary to keep them in an efficient and good working condition. He shall have immediate charge of all such repairs, but shall not, for such purpose, disable the machinery even temporarily, except by order of the commanding officer. He shall submit separate quarterly reports of the condition of said machinery to be forwarded for the information of each bureau concerned.

"*Duty in Regard to Stores.*

"654. (1) He shall perform the same duties in connection with the inventory, examination, invoice, receipts, accounts, issue, expenditures, preservation, care, survey and preparation of requisitions, reports and returns of engineer's stores and supplies, as are assigned to the equipment officer in connection with equipment stores and supplies. He shall be allowed a yeoman.

"(2) After making the proper substitution of names, the regulations for the performance of these duties will be found in articles 564, 565, 566, 567, 570, 571, 572 and 573.

"*To Keep a Coal Account.*

"655. (1) He shall keep an account of the expenditure of coal for various purposes, and shall furnish the executive officer with such information as he may desire for making the required coal report.

"*The Engineer Division.*

"656. (1) He shall, at quarters, command the engineer division. He shall make the usual report in regard to absentees, and perform such of the duties laid down in articles 642, 644 and 645 as may be required.

"(2) The engineer division shall consist of all engineer officers of the ship, of all warrant machinists, and of all enlisted men of the engineer force, except such of the latter, not to exceed one-third, as may be stationed in the powder division.

"(3) It shall be mustered at quarters at such place or places as may be designated by the captain.

"*Station Bills.*

"657. (1) He shall make out watch, quarter, station, fire and cleaning bills. They shall, after approval by the captain, be hung up in a conspicuous place in the engine rooms.

"(2) These bills shall clearly show the duty and station of every officer and man of his force under all conditions of service.

"*Station.*

"658. (1) He shall personally supervise the operation of the machinery in getting under way or coming to anchor, and also, as far as practicable, at all times when unusual care is required to be given to the working of the engines.

"(2) He shall frequently visit the engine rooms during the day, and at any time during the day or night when his presence or services there may be necessary.

"(3) When in the engine rooms he shall be responsible for all duty performed there.

"(4) He shall, every evening, carefully inspect his department and see that everything is in a satisfactory condition for the night; that there is no probability of accident from fire, from the introduction of sea water, or from other causes; and that all the rules and routine orders of the ship relating to his department are being obeyed. He shall, at 8 P. M., make a report of the result of his inspection to the executive officer, if the latter is the senior; otherwise to the captain.

"(5) He shall not be required to keep a watch unless, in the opinion of the captain, it becomes necessary.

"*Duties of Subordinates.*

"659. (1) He shall assign to the junior engineer officers their routine duties in connection with the care, preservation and repair of machinery, apportioning among them the entire machinery of the vessel for which he is responsible, so that

each officer shall have direct charge of some particular part of the machinery. Such division of the duties of the junior engineer officers shall not, however, relieve the engineer officer actually on duty or watch of his responsibility for the proper performance of the detailed work of the day.

"(2) When midshipmen are assigned to the engineer force, he shall see that they acquire a practical knowledge of their duties, and, as soon as, in his opinion, they are competent to take charge of watch under steam, by day or by night, or with a day's duty, he shall so report to the captain.

"(3) He shall cause the engineer officers to instruct the petty officers and men in their duties, and to give particular attention to the training of the firemen in the management of fires, both with natural and forced draft.

"*Precautions Against Fire.*

"660. (1) He shall, in the disposition and stowage of stores, and in the use of lights, take every possible precaution against fire.

"(2) He shall see that the apparatus in his charge for extinguishing fire is always kept ready for use.

"(3) He shall require the temperature of the coal bunkers to be taken every watch when practicable and recorded in the steam log. Should there be any indication of spontaneous combustion, it shall at once be reported to the officer of deck.

"*Responsibility for Good Order.*

"661. (1) He shall be responsible at all times, whether under way or at anchor, for the good order and cleanliness of the engineer department, and shall see that it is at no time left without sufficient watch under the charge of a petty officer.

"(2) Each day before 10 A. M., he shall examine the engine and firerooms, coal bunkers, storerooms, and other parts of his department and see that they are ready for inspection, and that the work of the day is progressing in a satisfactory manner.

"*Coal Bunkers.*

"662. (1) He shall frequently examine the coal bunkers with the view of ascertaining the quantity of coal actually on hand, as compared with the amount called for by the coal account. Should he discover any material excess or deficiency he shall at once report it to the captain.

"(2) Before coaling, he shall ascertain the condition of the bunkers and of all watertight openings, and shall satisfy himself that no unauthorized materials are stowed in the bunkers.

"(3) After coaling he shall report to the captain what bunkers are filled, whether the coaling port or scuttles have been closed as to be watertight, and what watertight doors or hatches are closed.

"*Noon Report.*

"663. He shall report to the captain at noon each day the amount of coal consumed for the preceding 24 hours and the amount remaining on hand, and when under way under steam, the number of revolutions of each propeller for the past 24 hours and the average number per minute when in operation.

"*Report Injuries.*

"664. (1) He shall report to the captain whenever a boiler is injured; also any accident or derangement to the motive engines or their dependencies.

"(2) Should he consider it necessary at any time to reduce the load on the boiler safety valves, he shall so report to the captain. Any change made in the load shall be recorded in the steam log.

"(3) Suggestions.—Whenever he deems it necessary, it shall be his duty to make written suggestions or reports to the captain concerning the motive machinery and its dependencies, or other fittings of the ship for which he is responsible.

"(4) Should he receive an order the execution of which would, in his opinion, injure the machinery or boilers, or tend to extravagance in the consumption of fuel, he shall report his opinion and suggest a remedy.

"*Shall Not Disable Machinery.*

"665. He shall not at any time, for the purpose of repairs, disable the machinery even temporarily, except by permission of the commanding officer.

"*Lighting and Hauling Fires.*

"666. He shall not permit fires to be lighted or hauled, except in cases of emergency, without orders from the commanding officer.

"*When to Turn the Engines.*

"667. He shall not permit the main engines to be turned except in the obedience to a signal from, or by permission of, the officer of the deck.

"*To Report any Infractions of Discipline.*

"668. He shall be careful that all duty under his supervision is performed in a diligent, faithful, zealous and orderly manner. He shall report any officer or man who fails in this respect, or who, while under him, commits any breach of discipline.

"*Reporting Work Necessary on Arriving in Port.*

"669. (1) He shall, whenever the vessel arrives in port, report to the captain in writing all work needed for the proper care and preservation of the machinery and boilers, stating separately the work that can be postponed, if necessary, and that which cannot, without injury, be delayed. He shall note opposite each item whether the work can or cannot be done by the force on board, together with an estimate of the time required.

"(2) Should no repairs to the machinery or boilers be needed, he shall report that fact to the captain in writing.

"(3) The date and nature of the report shall in every case be entered upon the steam log.

"*Steam Log.*

"670. (1) He shall have charge of the preparation and care of the steam log, which shall be begun upon the day the ship is placed in commission.

"(2) He shall keep the steam log in accordance with the instructions and directions as printed therein.

"(3) He shall cause to be entered in the steam log a record of all injuries to any of the engineer force while within the engineer department.

"(4) He shall, as soon after noon each day as practicable, present the steam log, complete to date, to the captain for his inspection.

"(5) He shall furnish to the navigator daily the data required for the ship's log book.

"(6) Entries in the steam log pertaining to matters and events outside of the engine and firerooms, such as wind, weather, speed, state of the sea, sail carried, course steered, draught of water, etc., shall be copied from the ship's log book, when recorded there.

"(7) He shall prepare and, at the end of each quarter, submit to the captain for transmission to the Navy Department a smooth copy of the steam log, which must be signed and approved in the same manner as the original.

"*Remark Book.*

"671. He shall record, in a book kept for the purpose, the location of all spare parts of the machinery; a complete statement of everything that transpires in his department which may be of use to his successor in familiarizing himself with the machinery of the vessel and its history, and, as soon as ascertained, the most efficient rates of expansion in the different cylinders for various speeds, noting the page or pages of the steam log from which the data was obtained.

"*Transmitting Official Papers.*

"672. He shall forward all official reports, communications and returns through the captain.

"*To Inform Executive Officer Concerning Conduct of Men.*

"673. He shall keep the executive officer informed of the sobriety and obedience of the enlisted men of the engineer force and of their proficiency in their respective ratings.

"*Absence or Disability.*

"674. During the temporary absence or disability of the senior engineer officer, the engineer officer next in rank remaining on board shall perform the duties of the senior in addition to his own. Should, however, the absence or disability of the senior extend to a considerable period, the captain may, at his discretion, relieve the engineer officer next in rank of his duties as a junior.

"SECTION 2.—OTHER ENGINEER OFFICERS.

"*General Duty.*

"675. (1) The duty of other engineer officers shall be arranged by the captain in accordance with the number on board fit for duty and the requirements of the ship. Whenever fires are lighted under the main boilers for steaming purposes, they shall perform duty by watches; under other circumstances they may be permitted to perform day's duty.

"(2) When performing duty by watches the engineer officer on duty shall exercise a close supervision over the warrant or other machinists in charge of the engine-room watch and over all others engaged in running or attendance on the engines and other machinery, the boilers and their appurtenances. He shall be vigilant throughout his watch, and shall remain in the vicinity of his sphere of duty and be in readiness to respond promptly to any call. He shall be in the engine rooms at all times when it is probable that it will be necessary to work the engines to signals, and also when the watches are being changed.

"(3) When on day's duty he shall exercise a general super-

vision over the engineer's department and all of the force employed therein, and, when important work is being executed, shall be diligent in attendance and supervision.

"*Watch Duty.*

"676. (1) When performing duty by watches the engineer officers shall in no case perform their duty in more than five reliefs. Ordinarily the duration of a watch shall be four hours, but when the number of engineer officers, exclusive to the senior engineer is reduced to three, the watches may be of not more than eight hours, and when reduced to two, of not more than twelve hours duration.

"(2) When the number of engineer officers, including the senior engineer, is reduced to two, these two officers shall perform duty by watches whenever the main engines are running. When the engines are not running, they may, with the permission of the captain, do day's duty.

"*Day's Duty.*

"677. (1) When doing day's duty, the engineer officers shall in no case perform this duty in more than four reliefs, and the length of duty shall be not more than 24 hours.

"(2) When there are two or more engineer officers, exclusive of the senior engineer, the former shall take the day's duty in turn, subject to the limitation of paragraph 1 of this article.

"(3) When the number of engineer officers, including the senior engineer, is reduced to two, these two officers shall take the day's duty in turn.

"*Engineer Officer of the Watch.*

"678. (1) The engineer officer about to take charge of the watch duty shall not relieve his predecessor until he has satisfied himself that the condition of the machinery is as turned over to him, and he will require the officers and petty officers on watch to report to him the condition of the men and parts of the department under their control.

"(2) The engineer officer of the watch shall use every effort to maintain the motive machinery and its dependencies in an efficient condition, and to prevent any accident or injury of same.

"(3) He shall cause to be executed promptly any order received from the deck by signal or otherwise.

"(4) He shall report at once to the officer of the deck any derangement or probable derangement of the machinery which may affect the maneuvering powers of the ship. He shall not permit the speed of the ship to be altered without orders from the deck, except through necessity.

"(5) He shall notify the senior engineer officer as soon as he discovers anything going wrong with the machinery or boilers.

"(6) He shall cause to be faithfully executed and observed all instructions and directions received from the senior engineer officer in reference to the use, care and preservation of the motive machinery, and in other professional duties with which the senior engineer officer is charged by these regulations.

"(7) He shall at all times carry out any instructions he may receive from proper authority.

"(8) He shall preserve order among subordinates in the engine and firerooms and place upon the report book the name of any man who is guilty of any infraction of discipline.

"(9) He shall keep the steam log and make such entries as are required by the instructions contained therein.

"(10) He shall, so far as is in his power, prevent any waste of coal, oil or other stores.

"(11) He shall not absent himself from the place of his duties unless regularly relieved.

"(12) Reports to the officer of the deck and to the senior engineer officer shall, when possible, be made through voice tubes. When this cannot be done, the reports shall be carried by some intelligent subordinate; in the case of important reports, both means shall be employed.

"*Engineer Officer Having the Day's Duty.*

"679. (1) The engineer officer having the day's duty shall be responsible for all work being done in the engineer department and all engineering work being done by any one of the engineer force. In the morning he shall see that the morning orders are properly executed. In the evening he shall inspect the department between 7 and 8 P. M. and satisfy himself that all cocks and valves are closed or otherwise, as ordered; that all unnecessary lights are out, that all watertight doors and hatches that do not interfere with the work going on are properly closed, and that all precautions have been taken to guard against fire, leakage or other accident; and he shall report to the senior engineer officer, before 8 P. M., the condition of the department.

"(2) He shall carry out all provisions in article 678, paragraphs 1, 5, 6, 7, 8, 9, 10, 12.

"*Orders, How Passed.*

"680. All orders regarding the management of the machinery or the men belonging to the engineer force shall, except in an emergency, be given through the engineer officer on duty.

"*Permission to Leave Ship.*

"681. Engineer officers shall, before applying for leave to be absent from the ship, obtain from the senior engineer officer permission to do so. Should the senior engineer officer refuse such permission he shall report his reasons for so doing to the captain.

"SECTION 6—WARRANT MACHINISTS.

"*General Duties.*

"801. (1) Warrant machinists shall act as assistants to the engineer officers of the ship in all that relates to the care and management of machinery and boilers and their appurtenances, and shall perform such duty as may be assigned them.

"(2) Routine duties in connection with the surveillance,

care and efficient condition of the machinery, boilers and mechanical appliances, and the cleanliness of bulkheads and compartments in the engineer department will be assigned them by the senior engineer officer.

"*Watch Duty.*

"802. (1) They shall stand regular engine-room watch in not more than four watches. While on duty as engine-room watch officers they shall be under the supervision of and be subject to the orders of the engineer officer on duty, and shall be governed by the provisions of article 678.

"(2) The length of the watch shall not exceed four hours while the main engines are running, and shall not exceed six hours at any time.

"(3) They may, with the approval of the captain, be relieved from watch duty while the main engines are not running, whenever any necessary work of repair or examination or other exigency requires their continued presence and attention.

"(4) They may, with the approval of the captain, be excused from watch from 'pipe down' at night till 'all hands' in the morning, when the fires are not lighted under the main boilers for steaming purposes.

"*When Less than Four on Board.*

"803. When the number of warrant machinists on board available for duty is reduced below four, chief machinists mates or competent machinists mates of lower rating may be assigned to duty as engine-room watch officers."

At present there are very few vessels on which the senior engineer has assigned to him as assistants commissioned officers who have had sufficient experience and training to properly carry out the requirements of these articles. Nearly all the officers, other than the senior engineer, on duty in the engineer departments of our naval vessels, are assigned presumably for instruction, and, for the most part, have not sufficient knowledge or engineering experience to make them of much material assistance to the senior engineer. On him,

then, rests not only the burden of carrying on all the duties of administration and supervision, for which the regulations contemplate the services of several officers (apparently three or four), but also the duty of instructing the junior line officers in engineering knowledge. It is no more than natural that under the pressure of the multiplied duties many matters conducive to high efficiency and economical performance are not looked after as they should be, and for this reason marine-engineering practice in the Navy does not, at present, possess that high, all-around efficiency that would be possible if our vessels were provided with a proper force of skilled and experienced engineer officers specially educated for the purpose. A greater number than two or three experienced commissioned engineer officers is not needed on any vessel, but one is certainly not enough for a vessel of 30,000 I.H.P.

Many of the senior engineer officers on our large vessels at present are line officers who were graduated from the engineering course at Annapolis before the amalgamation of the line and engineers, and who have had experience for a number of years in doing engineering duty on modern naval vessels. There are also other officers serving as senior engineers who were graduated as line officers, but who have had considerable experience in engineering since the passage of the personnel law. Such officers, not ex-engineers, have not, however, had the benefit of a special course in engineering, there being no such course for line officers since the passage of the personnel law.

A course of this kind is being revived by having a certain number of junior officers assigned to take some special instruction in engineering under the direction of the Bureau of Steam Engineering. In the same general manner a course in ordnance is being conducted under the direction of the Bureau of Ordnance. These special courses were established by an order of the Navy Department in 1904, on the joint recommendation of Rear Admiral Taylor, Chief of Bureau of Navigation, Rear Admiral Rae, Chief of Bureau of Steam Engineering, and Rear Admiral Converse, Chief of Bureau of

Ordnance. A few of the officers who have taken this special course have lately been assigned to duty as senior engineer officers.

There is, however, no definite law or order of the Navy Department in force requiring that officers who have taken this course shall do engineering duty, nor are there yet any definite standards or requirements to which, in taking this course, officers must conform. There is yet no established policy nor regulation concerning the detail for engineering duty of officers who have taken this course.

The condition at present existing is that the engineer departments of our vessels of war are in charge of senior engineer officers, some of whom were formerly in the separate engineer corps and others who were of the old line and who have specially taken up engineering. There are relatively few of the old line officers who have become proficient and properly qualified to be assigned to independent duty as senior engineers or to engineering billets on shore; and no practical steps (having the promise of efficient results) are being taken by the Navy Department to determine who, if any, of such line officers have become proficient in engineering duties. There are also at present on duty in the engineering departments a considerable number of line officers—lieutenants, ensigns and midshipmen—who are there almost entirely for instruction in engineering, and who therefore can not be counted upon to do independent engineering duty.

The captain of each ship is required to send a report to the Bureau of Navigation of the amount of engineering duty performed by officers. A general remark as to proficiency in such duties is also made by the Captain for entry on an officers' record. There is, however, no general standard of requirement for proficiency in engineering. During the past six years a number of officers have gone through the rank of midshipman, ensign and junior lieutenant without doing any engineering duty. Officers who have had no previous engineering experience have in several cases been ordered to large vessels as senior engineers.

WARRANT MACHINISTS.

The passage of the personnel law created the warrant machinists who now perform the watch-standing engineering duty in the Navy, and who are also charged with the immediate conduct of repairs, overhaul and operation of machinery. They are practical operating engineers, starting out as good mechanics, who have secured their positions by years of experience as enlisted men in the engineer departments of our naval vessels. The present method of appointment secures in them a body of efficient, practical engineers and high-class mechanics. As a body they are thoroughly efficient and well fitted to perform the duties required by the Naval Regulations. They are, however, with a few exceptions, men who possess what may be called but an elementary education. As a class they are not acquainted with theoretical and scientific engineering nor with the principles of designing and building. They have not had the military training as officers nor the educational training in naval military duties. Many of them are efficient marine engineers and fully as capable of taking charge of an engineer department as some of the commissioned officers of little or no engineering experience. Most warrant machinists are able to pass for a license as chief engineer of a merchant vessel of unlimited tonnage, and a large number of them have these licenses. However, for lack of sufficient education, scientific knowledge or military training the warrant machinists *as a body* are not and, in the nature of the case, cannot be properly qualified to be put in charge of the engineer departments of our vessels of war.

It must be remembered that this statement is made of them as a class and that there are individual exceptions. It must also be remembered that the control of the engineer department of a large vessel of war calls for more than does the control of the engineer department of a merchant vessel, and that there are many military duties connected with it for which men selected as warrant machinists neither are nor can be expected to be qualified in all respects.

ENGINEERING CONDITIONS AFLOAT.

Next let us inquire into the actual condition of the engineer departments of our naval vessels. First let us take the large armored vessels. Their condition is reasonably efficient, their machinery is kept in reasonable repair, and full designed power or an approximation thereto can be obtained in service. The amount of money spent in navy-yard repairs and engineering supplies, is however, quite outside of the limits of reasonable economy. This is due to a lack of sufficient supervision caused by the shortage of qualified officers to do it, also to the rather inefficient method of administrating navy-yard work and purchasing and furnishing naval supplies.

Another matter in which our naval vessels as a whole are very deficient is the consumption of coal and supplies. The coal consumption of our naval vessels materially exceeds figures obtained in modern up-to-date marine practice. This lack of economy is due in a large measure to deficiencies in design and construction.

On the small vessels, which have less of the care and supervision of experienced engineer officers, repairs are in many cases excessive and far beyond what they should be The condition of machinery on some vessels is even poor and in some cases serious accidents and breakdowns have occurred due to an insufficiency of properly trained personnel both in officers and enlisted men.

The general condition of the machinery of many of our torpedo boats and destroyers is not good, and many are unable to obtain their designed speed. Extensive and costly repairs to these vessels are constantly being made. The condition is due to the lack of officers and experienced men assigned to the duty of caring for the machinery of these craft, and especially to the lack of engineering experience and knowledge possessed by those officers placed in charge of machinery, often a midshipman or an ensign who had had no previous engineering experience.

One thing that is fast leading to a very serious condition in the engineering departments is the lack of any uniform instruction in regard to the administration of the engineer department, conduct of work, training and stationing of men. The only instructions that have any official warrant or authority are found in those portions of the naval regulations that relate to engineering matters. These are necessarily very general, and have not been modified lately to suit new conditions. The steaming instructions are now the same as they were in 1895, although naval machinery has been revolutionized during this time, steam pressure doubled, water-tube boilers, turbines and superheated steam introduced. As far as the organization of the engineer division is concerned no uniform directions are given. Each senior engineer follows out his own inclination and opinions. The same matters are treated entirely different on vessels that are alike.

Owing to this state of affairs officers and men trained in the engineer department of one vessel have to learn to do things in a different way when they are sent to another ship. This condition can be remedied if a uniform standard for the administration and organization of the engineer department were devised and enforced.

There are now no proper authoritative instructions for methods of care, overhaul and operation that apply to the newer vessels. The instructions in the regulations, as has been mentioned before, have not been revised to keep up with the changes in machinery.

No books are available which describe in detail the proper methods of operation of the machinery of our latest vessels. Books for the instruction of midshipmen at the Naval Academy are to be found, but these, being designed for the instruction of midshipmen, are in many cases too general. The principal printed matter in the line of information concerning our naval machinery are the numbers of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

It is, therefore, in a measure, difficult to gain a proper knowledge of the methods of care, operation and handling of

naval machinery except by actual experience, and by each individual intrusted with this duty finding out for himself by the process of trial and error.

There is no great difficulty in the way of securing standard methods of operation. All that is necessary would be to gather together the information from the different engineers in the service and publish the instructions under proper authority. The fact, however, remains that nothing of this character has been done, and the efficiency of naval engineering suffers accordingly.

The principal reason for this lack of attention in these matters is that there has been provided no force for doing the work. The Bureau of Steam Engineering is not provided with the necessary officers nor the civilian force to do it.

If there were at present an adequate proportion of sea-going line officers restricted to engineering duty as specialists some of these matters would receive more of their proper attention. Under present conditions each officer is required to be able to do so many different things that no one subject is gone into sufficiently to be thoroughly investigated; the tendency being for each one to get safely over with the work in hand by such means as are available and to leave the future to chance.

These comments are made with the idea of pointing out in what respects naval engineering matters are deficient and to show where the services of specially trained engineer officers are needed to make good these deficiencies. As compared with other navies, there are many things in which U. S. naval engineering excels, but the only way to maintain excellence is to remedy all weak points and defects that come to notice.

THE OUTLOOK FOR THE FUTURE AFLOAT.

With present outlook, in a few years all line officers who have had an engineering course at the Naval Academy will either be retired or will have reached ranks in advance of those from whom detail as engineer officers of vessels is made. The senior engineer officers will then have to be selected from

line officers whose previous experience, if any, will have been received under the present arrangement of a year, more or less, of engineering duty under instruction as assistant to the senior engineer. Moreover, such officers will not have had the benefit of any course in engineering except the rather short and superficial one provided for the midshipmen at the Naval Academy.

A question can very naturally be asked whether such officers as a class will be thoroughly competent to perform this duty and bring the machinery to the very highest state of efficiency. Will they be such as are best fitted to investigate the many technical engineering problems that will be coming up concerning methods and improvements in design and management? Will they be likely to understand the detailed essence of scientific naval engineering? The answer to the questions is perfectly obvious. It is folly to expect men of such little experience to be deeply versed in the technical details of a very involved subject just because they happen to have commissions as naval officers. The engineer departments of our complicated vessels will simply be put in charge of officers who are not familiar with them or with the methods of operating them, whose engineering experience will have consisted of a few months of instructional duty in the engineer department at some previous time. Several years may have intervened since such duty.

It is a serious fallacy to believe that the present course of three and one-half years at the Naval Academy, with its courses in mathematics, law, seamanship, navigation, ordnance, naval construction, military duties and the art of war all packed in with its course in steam engineering, can by itself fit an officer with the proper theoretical equipment to thoroughly understand the engineering knowledge that the control and management of a 30,000 I.H.P. engineer department requires. At present, time for study and research by officers outside of the duties that they are actually preforming is almost nil, everyone is more than busy with the details of his own work. If he is a watch and division officer the

requirements of his drills, battery and division occupy all his time, and he has no real time, opportunity or inclination to take up the study of engineering in addition.

The present course in engineering at Annapolis is not sufficient engineering education to thoroughly fit an officer for all the duties of an engineer officer afloat and ashore. To obtain additional knowledge a post-graduate course of some kind must be provided not only on question of design but also on care and operation for those officers who are to be assigned to duty in charge of the engineer departments of the important fighting vessels and the important engineering positions on shore.

EFFICIENCY OF WARRANT MACHINISTS.

In the system of appointment of warrant machinists as at present adopted and carried out, we have the promise of securing an efficient and thoroughly competent body of practical marine operating engineers for the purposes of taking engine-room watches and the immediate supervision of the mechanical work in the engineer department.

To obtain thorough engineering efficiency this body of practical men should be supervised and directed by highly trained, scientific and experienced officers who, having been trained in military and administrative duty, must also be thorough masters of the science of naval engineering both in theory and in practice. The average line officer under present conditions of training is not such an engineer, and can never be unless he neglects some of the other parts of his profession.

The warrant machinists, as a class, have not sufficient education and military training to fit them for independent authoritative administrative positions, such as that of the senior engineer of a high-powered naval vessel, the direction of the engineering department at a navy yard or the office of inspector of machinery at a large shipbuilding plant. There are among the warrant machinists a limited number who may become qualified in all respects for the performance of the

engineering duties of a naval officer both on shore and afloat. At present warrant machinists have the privilege of taking an examination for a commission under the same rules as gunners and boatswains, and two warrant machinists have been commissioned.

A warrant machinist, to secure a commission, must make himself proficient in a great many general and special naval duties which are entirely out of his environment, while performing his duties as a warrant machinist. Engineering is only one of the many subjects that must be mastered, but is the only one on which an officer performing the duties of a warrant machinist can properly inform himself. He has little or no chance to learn anything of military drill, navigation, modern seamanship, gunnery, handling vessels or the duties of the officer of the deck. Gunners and boatswains have a much better opportunity for becoming acquainted with the various duties other than engineering that a commissioned officer is required to know. The present arrangement places a severe handicap to securing a commission on the warrant machinist.

Another thing, if a warrant machinist secures a commission he may never be detailed for engineering duty, but may be ordered to other line duty with which he is necessarily more unfamiliar.

Warrant machinists who have mastered the engineering profession naturally desire to do engineering duty with which they are familiar; hence, a warrant machinist who is ambitious to advance himself is encountered with the project of having to learn a great many unfamiliar duties, being taken away from the duty he is familiar with, and then being required to do unfamiliar duty.

If it were arranged so that a warrant machinist could secure his commission on an examination in engineering subjects and could be restricted to engineering duty after receiving his commission, then there would be some equitable system for rewarding merit and extra professional ability in this corps.

If a special class of line officers for engineering duty is provided for, warrant machinists who have special abilities could be allowed to qualify themselves for the duties of these engineering specialists and be given commissions as line officers for engineering duty.

Such an arrangement would serve to heighten the tone of the whole corps of warrant machinists. It would provide for the bright, diligent, well informed and ambitious ones a real chance of promotion in line and in sympathy with their actual engineering duties.

This I believe to be what those warrant machinists who may be qualified for commissions really want. They desire the advantages of a commission, but also want engineering duty, recognizing that in that sphere they can serve the Government with more credit to themselves and to the Navy than if sent to unfamiliar duties distant from their training as engineers.

Any project for commissioning warrant machinists as a body is out of the question. There is no more real reason for this than there is to commission all boatswains and gunners. High educational attainments and thorough military training are absolutely essential to a commissioned officer. Warrant officers, as a body, do not have these attainments, and their duties do not require that they should have.

ENGINEERING MATTERS ON SHORE.

The engineering duty of the Navy on shore is a very large matter, and amounts to the expenditure of about five millions for repairs and eight millions for new construction each year.

The practical part of this work includes the conduct of the repairs and the maintenance in efficient condition of the motive power of all the vessels of the Navy, and the design and superintendence and construction of the machinery of vessels building. At present there are under construction thirteen first-class battleships, eight armored cruisers, three large scout cruisers, four submarines and a number of tugs.

As this work is one of considerable magnitude, it naturally follows that to secure efficiency in its administration a properly-trained and qualified force is necessary. There are now no provisions, in the present system of training, for training any officers to be put in charge of this work. The only indication of anything being done is the assignment of a limited number of junior officers to the Bureau of Steam Engineering for special engineering instruction. This special course has, however, as yet no promise of a definite existence, and is at any moment in danger of being discontinued.

The work of designing naval machinery, general supervision over repairs to naval machinery and the collection of engineering data is done at the Bureau of Steam Engineering. There is at the Bureau a civil force of 12 clerks, 16 draughtsmen, 2 messengers and 4 laborers. All civil employees are subject to the civil-service rules.

The draughtsmen are required to qualify in an examination for marine engine and boiler draughtsman, which examination is conducted by the Civil Service along lines recommended by the Navy Department. The pay of the draughtsmen is from $3.28 to $7.04 per day. The pay of the leading draughtsmen is small, considering the character of the work they are called upon to perform. A number of them are skilled and experienced designers of naval machinery. There is very little chance of promotion and no increase in pay for length of service, so that these conditions are naturally not very conducive toward developing or securing the highest class of expert designing engineering talent. It is owing to this that the Bureau is continually losing the services of excellent draughtsmen, more properly designers, who are attracted by higher pay elsewhere. There are few inducements now offered for an ambitious, talented marine-engineering draughtsman to enter the service of the Bureau of Steam Engineering where the limit of probable promotion ends with a pay of six dollars a day.

The work of designing naval machinery is now done by the draughtsmen under the supervision and direction of line

officers for engineering duty only, who were members of the former engineer corps and who have had the benefit of a course in designing machinery at the Naval Academy and many years of engineering experience at sea and on shore.

The number of such officers on duty at the Bureau has, however, been very inadequate for the proper carrying on of the work, and by reason of this dearth of officers many matters that to be thoroughly well handled should be taken in hand by officers with engineering experience afloat have been entrusted to civilian employees who, doing the best they can, have done remarkably well considering their lack of sea-going experience. The Bureau, moreover, has not been allowed to have a sufficient force of such civilian employees.

The work of naval engineering inspection is divided into two heads, Inspection of Machinery and Inspection of Material.

The work of inspection of machinery comprises the inspection of the construction and installation of the machinery of vessels building by contract. Inspectors of machinery are now (1906), located at the following places:

Newport News Shipbuilding and Drydock Co., building battleship *Minnesota*, armored cruisers *North Carolina* and *Montana*.

Wm. Cramps and Sons, building armored cruisers *Tennessee*, battleships *Mississippi*, *Idaho* and *South Carolina*.

New York Shipbuilding Co., building armored cruiser *Washington*, battleships *Kansas*, *New Hampshire* and *Michigan*.

Bath Iron Works, building battleship *Georgia*, scout cruiser *Chester*.

Neafie & Levy, building armored cruiser *St. Louis*.

Fore River Shipbuilding Co., building battleship *Vermont*, scout cruisers *Salem* and *Birmingham* four submarines.

Union Iron Works, building armored cruisers *California*, *South Dakota* and *Milwaukee*.

Moran Bros., building battleship *Nebraska*.

It is only occasionally that an inspector of machinery has

an officer as assistant. There are, therefore, practically no understudies gaining experience in this work, consequently, no properly trained reliefs are being obtained to take up this work when the officers now restricted to engineering duty are retired.

Each inspector has a limited force of clerks, draughtsmen and special mechanics appointed under civil-service rules. This force is in many cases inadequate to properly perform the duties of inspection. The pay allowed by the Navy Department for such civil force is in numerous cases hardly commensurate with the character of the service required. Special mechanics, supposedly qualified to inspect the installation of naval machinery and to conduct tests of same, are allowed the pay of $3.56 per diem. This is hardly enough to attract very high classed-mechanics.

To properly perform the duties of inspector of machinery requires years of engineering experience, both on shore and afloat, and a much more thorough knowledge of technical naval engineering than line officers are able to obtain from the present limited course in engineering at the Naval Academy.

Practically none of the younger line officers are now being assigned to gain the necessary experience as assistants that will enable them to properly perform the duties of inspector of machinery. Civilians having the necessary experience and training are not to be found, and in no case would they have the naval sea-going experience which is so very essential.

INSPECTION OF ENGINEERING MATERIAL.

This work is divided among nine offices, each office doing the inspection work for a certain district.

The following extract from the report of the Chief of Bureau of Steam Engineering will show the general scope of this work.

"INSPECTION OF ENGINEERING MATERIAL.

"The total number of pounds inspected and passed for the different bureaus of the Navy Department is as follows:

"For Bureau of—

Steam Engineering,	19,892,746
Yards and Docks,	24,568,109
Supplies and Accounts,	1,234,964
Construction and Repair	667,876
Equipment,	3,368,809
Ordnance,	381,343
Total,	50,113,847

"The total number of firms and manufacturing establishments doing work for the Government requiring inspection is 318, an increase of 32 per cent. over last year.

"Since these manufacturing establishments are scattered over a wide area of territory, the Bureau has established at convenient points headquarters for nine inspection districts.

"It has been the Bureau's endeavor to keep on duty at each headquarters a commissioned line officer of experience in the inspection of engineering material. Unfortunately, owing to the scarcity of officers available for such duty, it has not been practicable during the past year to carry out the above mentioned design. At present but six commissioned officers are available for the nine inspection districts. An officer who has more than one district to look after is greatly hampered in his work owing to the unavoidable time lost traveling from one district to another. The result is that the inspection work has suffered at times, and delay has ensued, because the naval inspector, who is supposed to decide promptly on questions of inspection as they arise, has not always been on the spot in the particular district where the question may have arisen.

"Then again, when so much of the naval inspector's time is consumed in traveling from one district to another it is impossible for him to exercise the close supervision of the work of any one district that is necessary to prevent friction between contractors and the assistant inspectors.

"The Bureau renews its recommendation made in last year's

report, namely: That young line officers be ordered to duty with the present naval inspectors of engineering material to be trained in the important duties of determining the fitness of the materials that make up the successful war ship.

"To assist the naval inspectors of engineering material the Bureau has a staff of civilian assistant inspectors, obtained by competitive examinations under civil-service rules. At the two important manufacturing centers of Pittsburg and South Bethlehem, Pa., the Bureau has well-equipped chemical laboratories with competent chemists. In these two laboratories are made all the chemical analyses required by the specifications governing the inspection of engineering materials.

"The character of the materials inspected is most varied. Among the most important are steel forgings for the heavy shafting and other moving parts of marine engines; gun forgings; anchors and anchor chains; steel boiler plates; castings of steel, iron and composition metal for marine engines; boiler tubes and condenser tubes; steel steam pipe and pipe of copper and brass; sheet copper and rolled sheets of composition material.

"The Bureau also inspects finished boilers, engines, and electric motors; power tools for machine shops; pumps for use on board ships; valves and engine fittings of all kinds; ice machines for naval use, and the forced-draft blowers used on board ship. The inspection of all auxiliary machinery used on board ship, within this Bureau's cognizance, is receiving careful attention, since it is realized that the efficiency of a vessel's machinery, as a whole, depends in large degree upon the trustworthiness of these small machines.

"Nearly all shipbuilding establishments buy these important auxiliaries from firms making a specialty of that particular work. In the past these finished auxiliaries for Government ships were sent to the shipyard, where only a superficial inspection of the finished product was possible. Now the Bureau insists upon a full and careful inspection of the materials entering into these auxiliary engines, as well as an inspection and test of the finished product before installation

on board ship. The good result of this method is very gratifying to the Bureau.

"This Bureau inspects all the structural material used in the construction of the storehouses and shops for navy yards and naval stations, also the structural material and machinery for coal-handling apparatus and coal-storage plants. The Bureau inspected all the material for the great floating drydocks recently built, and inspects the pumping plant for other new drydocks; material for steam and electric cranes for drydocks and for shops, as well as the finished cranes, are also inspected by the Bureau.

"The headquarters of the inspection districts are as follows:

"*Homestead Steel Works, Munhall, Pa.*—One officer, who also has charge at Shelby, with seven civilian assistants, one of whom has charge of the Bureau's chemical laboratory, do the inspection work of this district, which includes in addition to the great steel works of the Carnegie Steel Company, 53 manufacturing establishments doing Government work requiring inspection.

"*Midvale Steel Works, Nicetown, Philadelphia, Pa.*—One officer and three civilian assistants do the inspection work of this district, where 38 firms and manufacturing establishments in Philadelphia and vicinity do Government work requiring inspection. At Midvale and at Bethlehem are made nearly all the large engine forgings of nickel-steel used in naval machinery.

"*Bethlehem Steel Company, South Bethlehem, Pa.*—One officer and two civilian assistant inspectors, one of whom has charge of the Bureau's chemical laboratory, do all the inspection work of the district, which includes five firms and manufacturing establishments doing Government work requiring inspection. The naval inspector of engineering material is also ordnance inspector.

"*American Steel-Casting Company, Chester, Pa.*—One officer, the same who has charge at Midvale, and one civilian assistant do the inspection work of this district. In this district are made a large proportion of the steel castings used in

the engines of our war ships. Many anchors for the Bureau of Equipment are also made in this district and inspected by this Bureau's inspector. There are in this district seven firms and manufacturing establishments doing Government work requiring inspection. The naval inspector in charge of this district is also inspector of machinery for the Navy at the works of Harlan & Hollingsworth, Wilmington, Del.

"*Harrisburg, Pa., room 21, post-office building.*—One officer, the same who has charge of the Midvale district, and two civilian assistants do the inspection work of this district. There are in this district twenty-one firms and manufacturing establishments doing Government work requiring inspection. Many heavy anchor chains are made in this district and inspected by this Bureau.

"*Brooklyn, N. Y., room 5, post-office building.*—In this important district two officers, one on the retired list, and three civilian assistants inspect the work done for the Government by fifty firms and manufacturing establishments. These places are located within a comparatively small area, so that inspection work is carried on without the great loss of time made necessary when the area to be covered by the inspectors is a large one. In this district are made many important auxiliary engines for naval vessels; the inspection of the material for these auxiliaries, as well as the inspection and test of the finished engines, must be as carefully attended to as the same work for the main engines themselves. The naval inspector of engineering material is also ordnance inspector.

"*District of Connecticut, with headquarters at Hartford, Conn., room 1, post-office building.*—One officer and two civilian assistants do the inspection work of this district. There are in this district thirty-five firms and manufacturing establishments doing work for the Government requiring inspection. In this district are made practically all the condenser tubes for Government vessels. The inspection of these condenser tubes is work of the greatest importance, for the Bureau recognizes that the relatively short life of these tubes

is a weak point in the endurance of naval machinery. The Bureau is endeavoring in every possible way to increase the lifetime of condenser tubes, and to this end the naval inspector of material in the district is directed to cooperate with the tube makers in their endeavors to turn out a tube that shall have more lasting qualities than the ones at present obtainable. In this district a large part of the copper and brass pipe used in the Navy is made, also rolled-composition material of various kinds.

"*District of the Middle West, headquarters at Shelby, Ohio.*—One officer, one warrant officer and one civilian assistant do the inspection work of this district. There are in the district sixty-three firms and manufacturing establishments doing Government work requiring inspection. At Shelby are made a large proportion of the smaller-sized steel boiler tubes for the Navy.

"*District of Massachusetts, with headquarters at Boston, room 102, post-office building.*—One officer and one civilian assistant do the inspection work of this district. There are in the district forty-six firms and manufacturing establishments doing Government work requiring inspection. These places are for the most part in Boston and vicinity. In this district are made many blower engines and steam pumps for the Navy, all requiring close inspection during manufacture."

As in the case of the inspectors of machinery, no young officers as assistants are provided, hence there are no understudies for these positions.

The inspection of engineering material is work of utmost importance to naval efficiency. The officer in charge of these offices, besides having had sea-going naval experience, must also have special expert knowledge of the manufacture and manner of testing engineering materials and machinery.

There are still a number of officers (ex-engineers) who are thoroughly qualified for this work, but in a few years their services will not be available, and now no one is being trained to take up this field of work.

NAVY YARD WORK.

The work of repairing and rebuilding naval machinery is done by the steam engineering department of the navy yards.

The engineering plant at such yards as those at New York or Boston is worth several millions of dollars, and to be efficiently conducted will require an experienced naval engineer to have charge and several officers well qualified in engineering to serve as assistants.

At the New York yard there are at times as many as thirty large vessels under repairs. It is needless to say that more than one or two officers are required to supervise this work at such times.

The engineering work of officers at navy yards includes the making of estimates for repairs, authorizing and deciding upon their necessity, preparing designs for alterations and repairs; and supervising and conducting the work when authorized. This is, of course, special work, and none other than a naval engineer of experience and training can thoroughly perform the duties required.

The line officer, as now trained, has neither sufficient engineering knowledge nor experience; the civilian engineer has no sea-going naval experience and only a limited knowledge of naval matters. A line officer who has specialized in engineering is the only one that can be depended upon to properly perform this work.

It is in the engineering work on shore that the greatest deficiencies exist. For the past five years there has been neither a sufficient number of officers nor a sufficient civilian force to efficiently perform all the naval engineering duties. The few officers who are qualified and who have had any extensive experience in the work are fast leaving the service by retirement and resignation, and none are being trained to take their places. There is no dearth of good material among the younger line officers for furnishing thoroughly competent inspectors, but none are being allotted for training for this purpose.

Unless the machinery of our naval vessels is kept up to the latest and improved state, both in design and construction, and also in methods of care and operation, our naval efficiency will suffer most seriously. It will not be kept in this state of efficiency unless a responsible body of officers who have had actual and extended experience, both in designing and operating, an engineering and military training and a scientific naval engineering and military education, is provided in the Navy.

The fact that ships must necessarily be built on shore and that materials for their machinery must be obtained there, seems to bring up the contention that civilian engineers who have no naval experience and who are not to go to sea can be placed in charge of the work of directing and supervising the building and repairing of naval machinery. Such engineers can be employed and, with present lack of officers, must necessarily be employed to a considerable extent as draughtsmen, computers and designers. But unless those supervising the design of naval machinery have had recent extended experience at sea in naval vessels they cannot know how to arrange this work so as to secure the highest state of operative efficiency. It must be remembered that the highest actual operative efficiency in service is the result desired, and unless the condition of actual operation is studied and observed by those who are to design and direct the construction of new machinery and equipment no very practical improvement is probable. It will be manifestly hopeless to expect that any body of engineers will be able to develop and produce machinery best suited for this purpose unless they have had, in some way, a chance to become personally, actually and intimately familiar with the operation of naval machinery at sea. The fact that large shipbuilding yards are continually taking engineers and naval constructors from the Navy to take charge and direct their work shows that the shipbuilder, who only has to build the ship, recognizes the need of actual naval experience to direct the building of naval vessels that they deliver to the Government.

Officers properly qualified to perform the duties of supervising and conducting the naval engineering work on shore can only be provided with certainty from one source, that is the line of the Navy. To obtain a proper knowledge of the technical details of this work such line officers must specialize in engineering.

If a certain number of line officers (say 100) with a reasonable number of years' experience, are selected to specialize in engineering and are assigned to duty as such engineering specialists, as was recommended in the report of the Chief of Bureau of Steam Engineering, and advocated in the articles written by Lieut. Comdr. Chandler, Prof. Hollis, Lieut. Comdr. Beach and Lieut. Holmes, and a sufficient clerical and technical civilian force as the needs demand, is provided, naval engineering matters will be placed on a proper basis and a degree of efficiency unparalleled in history and superior to that of any other navy, will in a short time be secured.

THE NAVAL PERSONNEL LAW: WHAT IT DID AND WHAT IT DID NOT DO.

The personnel law is based on the broad principle that the direction of all the fighting personnel and the handling of all material that goes to make up the fighting efficiency of the Navy must be under the control of the military officers of the Navy.

It holds that to educate and train an officer for the duties of military naval command he must receive an elementary or grounding knowledge in all the various matters that go to make the material and personnel of the Navy; and that among the important items of which knowledge is necessary, is engineering. Also that those in responsible control of the engineer department of the naval vessels, of engineering repairs at navy yards and of the work of designing naval machinery and of the supervision and inspection of the construction of the same, must have a sea-going naval and military training. It conforms to the idea that the general military naval training and the securing of the fundamental principles

of general naval knowledge can best be secured by training all officers who are to exercise command and authority over the fighting personnel in the same way, by means of the course at the Naval Academy. This is to establish at the beginning of their naval career certain uniform ideas of the essential general matters affecting the duties of an officer and the requirements of the Navy and of its personnel.

It is designed that unity of source and uniformity of early education and training will produce a community of general knowledge and ideals and a lasting community of sentiment and interest.

To secure these ends the personnel law provided that all officers of the line must go through the same course at the Naval Academy and that after graduation from that institution they are to be available for any duty in connection with the Navy not falling under the jurisdiction of the staff. This includes all command, navigation, ordnance, engineering and

NOTE.—Various statements are frequently made that the present course in the department of steam engineering at the Naval Academy is a better course than that given to the cadet engineers or cadets of the engineer's division. Such statements prove too much. It amounts to saying that a midshipman can as well and thoroughly learn several things as he can learn one by placing the same total time on it. Designing and experimental engineering is not taught at all. Thermodynamics is only vaguely touched upon, and building and construction is but superficially taught. There is not nearly sufficient time given to have anything but a general and elementary course in practical naval operating engineering.

The Naval Academy is well equipped for a good engineering course, but unless the students can spend sufficient time, is of little value.

The engineering course at the Naval Academy is sufficient to ground the young officer in a general conception of the engineer department of naval vessels and the ordinary methods of care and operation. This is all that is necessary for the training for the average officer for the general duties on board ship. But it is not sufficient for the more intricate and technical engineering work of designing, inspecting and building, nor sufficient to produce the highest excellence in the operation of marine machinery.

The midshipmen selected for the construction corps are given a three-years' technical post-graduate course. Naval engineering is as much, if not more, of an intricate subject than naval construction, and yet we are at present expecting to develop officers versed in this science who have not had a technical course in engineering and only interrupted and indefinite periods of engineering experience.

equipment duties afloat and all duty under cognizance of Bureaus of Navigation, Ordnance, Steam Engineering and Equipment on shore.

The following are some of the things that the personnel law failed to do, either by reason of inherent defects or by failure to carry out its intent.

It failed to designate with sufficient exactness how the duties between deck and engine room were to be divided. It named no specific, satisfactory standard requirement of engineering knowledge that all line officers must conform to. (It did, however, require the former engineer officers to qualify by an examination for the old line duties.)

It designated no means by which the old line officers were to acquire any additional engineering experience than they had previously.

(The midshipmen at the Naval Academy were provided with a better engineering course than had previously been given to the *line* cadets, but this course in no particular covers the scope of the course that was provided for the cadet engineers or for the cadets of the engineer division. This course is at present too elementary and too short and superficial to properly train men to become designing and constructing engineers and is even deficient as a training for operating engineers. As an engineering education it in no way approaches in scope and detail the engineering courses of high-classed technical colleges.—See Note.)

It provided in no way for securing officers specially expert in any of the special technical branches, though it goes without saying that to secure naval efficiency such special expert knowledge is absolutely necessary. Neither did the law create conditions tending to develop special study among officers or encourage any to specialize or excel in knowledge of any one subject. This produces a tendency for a wide general knowledge, but also general mediocricy in any special subject among officers, and also prevents the realization of excellence in any one particular thing.

It is the actual execution of the law, and not the law itself,

that must be examined in judging the conditions it has produced and the necessity of any alterations or change.

After the passage of the personnel law nearly all of the ex-engineer officers who were not restricted to engineering duty were transferred to deck duty, and most of them have been doing deck duty ever since. The line officers other than midshipmen detailed for engineering duty were very few, and those who were detailed were assigned for such short periods and under such unfavorable conditions for training as engineers that they did not acquire a very great amount of engineering knowledge.

The removal of the ex-engineers to line duties left very few officers for detail to the very important engineering duties on shore at navy yards, ship-building plants, offices of inspector of machinery, Bureau of Steam Engineering, &c. This resulted in the unavoidable set back of this part of naval-engineering work, the results of which can often be seen when a new ship is commissioned and in the enormous amount of money now being spent for alterations in vessels newly built. It is also a very regrettable fact that our naval machinery is not by any means as efficient or as well designed as it might be if matters were more thoroughly investigated and a proper force for carrying on the work had been provided. A large part of this engineering work on shore has been done and is being done by officers of little engineering experience and by civilians who are non-naval men. To secure thorough efficiency, sea-going engineer officers should perform a large part of the work now being done by these various inexperienced officers and civilians untrained to and lacking a thorough knowledge of its requirements.

(It is not meant to detract in any way from the faithful work that is being done by such civilians. They are doing about the best that the conditions will allow, and are in many cases underpaid for the character of the service rendered, but in the nature of the case they cannot perform special duties that require the training and sea-going experience of an officer.)

The general result of the passage of the personnel law is:

Line officers, as a body, have more engineering knowledge, which naturally increases their efficiency for command. This is as was intended, and in this the law is an unqualified success.

All the personnel and material on our vessels of war is being controlled by officers who have had the same general military training and who have naturally a military as well as an engineering ideal of efficiency. This is the principal advantage that the personnel law accomplished and it is of incalculable value. This is where amalgamation is a thorough success.

Our officers doing engineering duty, as a class, are much less expert and have a very considerable less experience in engineering than if the amalgamation had never taken place and a separate engineer corps had been maintained, or if engineering specialists were provided, as recommended by most naval officers who have written on this subject and as recommended by the Chief of Bureau of Steam Engineering.

The naval engineering work on shore has suffered severely. The work of designing machinery, inspection of material, construction of machinery, work of investigating engineering problems, securing data and information concerning the efficient operation of naval machinery and the work of conducting repairs to naval machinery is not being done nearly as well as if there had been a separate engineer corps or a special branch of specialists. This is caused by lack of trained engineer officers and to the fact that a large part of the work has of necessity been turned over to civilians untrained and inexperienced in naval matters.

The condition of the machinery of many vessels in the Navy is not as good as if a separate engineer corps had been provided.

The amount of money spent for engineering repairs and supplies is more than if an efficient separate corps of engineers had been maintained or engineering specialists provided.

These ill effects last mentioned can be readily remedied if the general recommendations made by the Engineer-in-Chief are carried out.

It will be seen that it is the engineering work of the Navy, and more especially the engineering work on shore, that has been the sufferer. This being the case, the natural thing to do is to provide means for supplying the needs of the engineering work without detracting from the great good that the personnel law has done in other lines. This simply means to provide a sufficient number of officers specially trained in engineering to take hold of the engineering matters that are now on the road to deterioration. The only practical way to do this is to take an allotted portion (about 10 per cent. of those above rank of ensign) of line officers who have the best engineering qualifications and use them to do the engineering work, and then provide some means for securing a regular supply of such officer-specialists for the future. A thoroughly feasible method is that recommended by the Engineer-in-Chief. He is naturally the one person to have an authoritative say in the matter. His recommendations should be carried out in principle, at least, even if some of the details are modified to some extent.

An article on this subject which has, perhaps, attracted more attention than any other, is the one written by Lieut. Comdr. Chandler, in the "U. S. Naval Institute." This article states the general condition of affairs quite plainly. It is, however, more sanguine of the thoroughness of the engineering course at the Naval Academy than I consider the facts warrant. It also, I fear, serves to give the impression that things are not as black as they have been painted, and that we are getting along very well in engineering matters. The present condition is not one to be satisfied with. Engineering matters are not as good as they should be, and our efficiency as a naval power in time of war is going to suffer severely from our deficiency in engineering.

There is a condition that must be met soon. It is that we have no adequate body of officers properly qualified to perform the higher duties of naval engineering at sea and more especially on shore. No means have been taken to remedy this state of affairs, and the conditions are getting worse. Al-

though it may be able to provide for all that is necessary under the provisions of the personnel law, the fact remains that it is not being done. The essential idea of amalgamation is correct and has suffered little attack from those in the Navy. But the lack of provision for securing specialists to do the special work is the point that has been so largely commented upon and criticised by those directly interested in naval engineering.

Specialists are also needed in ordnance, electricity, torpedoes, pilotage and astronomy. They are needed in all of the special branches for the same reasons that they are needed in Engineering. If they were provided for, a surprising increase in the efficiency of our naval material would result. It may, however, be remarked that these other specialties have not received as great a shock of disregard as Naval Engineering has received during the last half decade.

Naval-engineering work of designing and building must be controlled and conducted, supervised and directed by the same class of officers that the country will hold responsible for success or defeat in battle. This work must be under the control of those who have been to sea, who have operated and controlled and been responsible for these mighty masses of machinery when acted upon by the mighty forces of nature. The moment the control of building, designing and repairing of vessels and their machinery goes out of the hands of those who have gone extensively to sea in fighting ships, then there will be made costly mistakes and blunders in the design and state of repair of these fighting weapons. The fact that the design of our vessels is at present and has been to a considerable extent controlled by sea-going officers has enabled our vessels to be, in general, superior in many matters to those of other navies. At present the most serious mistakes are those in which the opinions of the sea-going officers, who are actually responsible for obtaining the results, have not been properly considered or are overruled.

The *Bennington* disaster is but an outcropping of the untenable conditions that prevail in certain quarters. This dis-

aster and various other accidents, and the necessity for costly repairs to the machinery of new vessels, are simply a few things that point out to us that engineering conditions are not all right at present. They are far from being all right. They are often quite unsatisfactory.

It is not now a question of whether the personnel law as a whole is a success or whether the amalgamation of the line and engineers was a benefit. But it is a question of getting for our Navy a sufficient number of thoroughly qualified officers to look after the engineering duty both afloat and ashore and in arranging conditions so that such a body of engineering officers can take hold and at once stop the backward movement that has set in.

The oft-repeated citing of the fact that at one time there were on vessels of war soldiers to fight and sailors to sail, and that at a later date these two bodies were merged into one that did both the fighting and the sailing, is no argument whatever for the necessity or the continuation of the present go-as-you-please hit-or-miss conditions that now exist among the official personnel of the Navy as far as training and detail for special technical duty is concerned. To cite this ancient history and to apply it in the abstract is fallacious argument. Modern conditions must be met in a modern way, and reasoning from examples of ancient history is in no way germane to the question. The general principle of amalgamation is desirable, necessary and indispensable to thorough naval efficiency. Its necessity is grounded on the same needs that a nation has for a common language.

Engineering belongs to the line and should be kept there. Those who advocate the establishing of a new, separate staff engineer corps are in error and are reasoning in the past. But it is also indispensable that specialists be provided for, and encouraged to develop their specialties to the highest degree of excellence not only in engineering but also in gunnery and ordnance, in torpedoes and electricity, in hydrography and astronomy, and any other specialty that may be required for naval needs.

The personnel law provided much that was desired, but it is not complete; it only goes part way, and then leaves things to chance or further development. Further development is now what is wanted. The personnel law has reached nearly the desired point in providing for the general features, education and training. The next thing is to make proper and adequate provision for the special features and training. What is wanted is an amalgamation of ideas, interests and aims, but to secure the ideal results from such an amalgamation specializing to the very highest degree is necessary.

U. S. BATTLESHIPS *MISSISSIPPI* AND *IDAHO.*

DESCRIPTION OF MACHINERY AND OFFICIAL TRIALS.

The *Mississippi* and her sister ship, the *Idaho*, are twin-screw armored battleships built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa. The contracts for these two vessels were signed January 25, 1904, the price for each being $2,999,500. These prices do not include the armor and armor bolts (exclusive of protective deck), ordnance and ordnance outfit and certain articles supplied by the Government.

The main engines were required to develop ten thousand indicated horsepower, when making one hundred and twenty revolutions per minute, with a steam pressure of two hundred and fifty pounds at the high-pressure cylinder.

The guaranteed speed of the ships was seventeen knots per hour for four hours.

PRINCIPAL DIMENSIONS OF HULL.

Length on load water line, feet	375
between perpendiculars, feet	375
over all, feet	382
Breadth, extreme to outside of armor, feet	77
Trial displacement, tons, about	13,000
draught to bottom of keel, feet and inches	24-8

ELECTRIC PLANT.

There is installed and fitted complete an electric generating plant consisting of eight 100-kilowatt generating sets, all of 125 volts pressure at the terminals. These sets are located in two independent dynamo rooms.

Each set consists of an electric generator directly coupled to a steam engine, and both mounted on a common bedplate.

U. S. S. "MISSISSIPPI."

The generating sets and the engines and dynamos conform in all respects to the latest requirements of the specifications for the United States Navy.

ANCHOR WINDLASS.

There is a steam anchor windlass located in the windlass inclosure on the upper deck, which is provided with two wild-cats, the design being suitable for handling anchors of about 14,300 pounds, each with 2½-inch chain. The windlass is of the worm-gear type.

The windlass engine is designed for a working steam pressure of 150 pounds per square inch, but is able to withstand the full boiler pressure.

On the trial of the *Mississippi* both anchors were let go in twenty-eight fathoms of water, about fifty fathoms being veered on the port chain, and the starboard chain being veered to the bitter end. While heaving in both anchors, and while heaving in the starboard anchor after the port anchor was up, the windlass maintained a uniform speed. The wild-cats took the shackles and the swivel without slipping or surging. The engine worked in a very satisfactory manner, and there was no heating of the worm wheel or thrust block.

The tests of the anchor engine of the *Idaho*, on the official trials of that vessel, were equally satisfactory.

STEERING ENGINE.

The steering gear is located aft, and is of the standard type of the Bureau of Construction and Repair, consisting of a right and left-hand screw with traversing nuts directly connected, by side rods, to a crosshead on the rudder stock.

The steering engine is capable of putting the rudder from hard a port to hard a starboard, and *vice versa*, in twenty seconds, with a working steam pressure of 150 pounds per square inch.

The engine, however, is of sufficient strength to withstand operation under full boiler pressure.

PROPELLING MACHINERY.

There are two 3-cylinder, triple-expansion, outboard-turning engines of the vertical, inverted, direct-connected type, in two watertight compartments, separated by a fore-and-aft watertight bulkhead.

The order of the cylinders, beginning forward, are high pressure, intermediate pressure and low pressure.

The cranks are at angles of 120 degrees to each other, the intermediate following the high pressure, and the low pressure following the intermediate pressure.

The frames of the engines consist of forged-steel columns braced by forged-steel stays. The engine bedplates are of cast-iron supported on the keelson plates. All crank, line and propeller shafting is hollow. The shafts, piston rods, connecting rods and working parts generally are of forged, open-hearth steel.

The main valves are worked by the Stevenson link motion with double-bar links. There is one piston valve for the high-pressure cylinder and two each for the intermediate and the low-pressure cylinders.

REVERSING AND TURNING GEAR.

Each main engine has a reversing gear of the usual floating-lever, oil-controlled type.

In each engine room there is a double engine for turning the main engines, with steam at 100 pounds pressure. This engine drives, by worm gearing, a second worm which may be made at will to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves.

Provision is made for turning by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P. diameter, inches	25½
I.P. diameter, inches	42
L.P. diameter, inches	69
Stroke of all pistons, inches	48
Valves, H.P., one for each cylinder, inches	14
I.P., two for each cylinder, inches	15½
L.P., two for each cylinder, inches	25¾

Valve stems, H.P. diameter, inches	2¾
I.P. diameter, inches	2¾
L.P. diameter, inches	2¾
diameter through valves, inches	1⅝
Piston rods, diameter, inches	6
axial holes, I.P., inches	2
L.P., inches	2
Connecting rod, length from center to center, inches	96
crosshead end, diameter, inches	5½
crank end, diameter, inches	6¾
Crank shaft, number of sections	3
diameter, inches	13½
axial hole, inches	7½
length, feet and inches	24–05
Coupling disks, inches	25½
thickness, inches	3
Crank pin, diameter, inches	14
axial hole, inches	7½
length, inches	15
Thrust shaft, diameter, inches	12¾
axial hole, inches	07½
length, feet	20
Collars, number on each shaft	11
diameter, inches	21¼
thickness, inches	02
space between, inches	04
Line shaft, diameter, inches	12¾
axial hole, inches	07½
length, feet and inches	15–10
Stern-tube shaft, diameter, inches	13¾
axial hole, inches	07½
length, feet and inches	37–08½
Propeller shaft, diameter, inches	12⅝
axial hole, inches	07½
length, feet and inches	29–05

PROPELLERS.

There are two 3-blade propellers, both outboard turning for ahead motion. The blades and the hub are of manganese-bronze.

The dimensions of the propellers are as follows:

Diameter, feet and inches	16–06
Pitch, as set, mean, feet	17
adjustable from 16 feet 3 inches to	18
Ratio of diameter to pitch	1.03

Area, projected, square feet	62.3
helicoidal, square feet	73.5
disk, square feet	214.0
Height of lower tip of blade above keel, inches	10½
Immersion of upper tip of blade at low draught, inches	87¾

CONDENSERS.

Main Condensers.—There is one main condenser in each engine room. The shell is of steel, the water chests of composition and the tubes of composition. Each main condenser has a total cooling surface of 6,960 square feet.

Auxiliary Condensers.—There is one auxiliary condenser in each engine room having a total cooling surface of 380 square feet.

Dynamo Condensers.—There are two dynamo condensers, each having a cooling surface of 951 square feet.

FEED HEATERS.

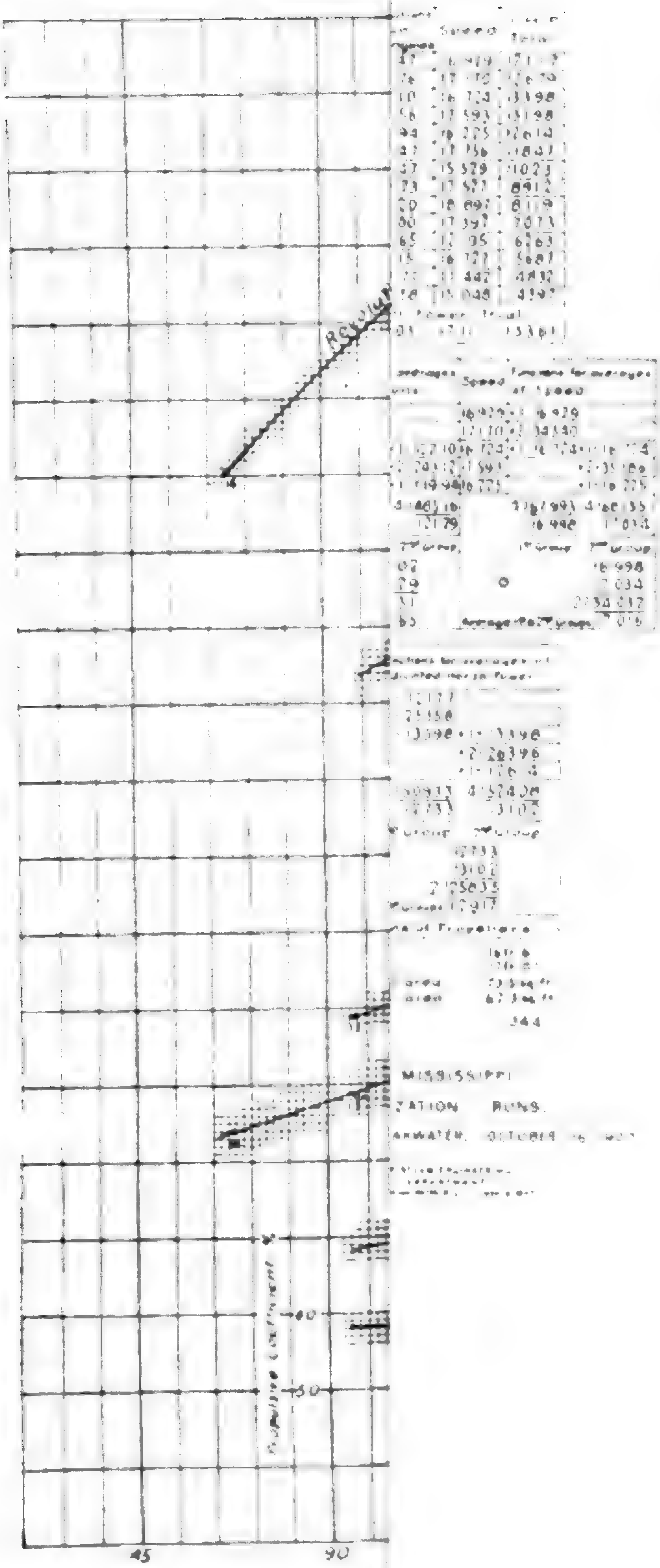
There is a feed heater in each engine room having a heating surface of 601 square feet.

PUMPS.

The pumps are in accordance with the following table:

DATA OF PUMPS.

Auxiliary pumps.	Number.	Type, make and location.	Steam cylinders. Number.	Steam cylinders. Diameter, inches.	Steam cylinders. Diameter piston rod, inches.	Steam cylinders. Stroke, inches.	Water cylinders. Number.	Water cylinders. Diameter, inches.	Water cylinders. Diameter piston rod, inches.	Water cylinders. Stroke, inches.
Main air	2	Featherweight, Blake, engine room	2	9	1½	18	2	18	1¾	18
Main circulating	2	Engine-driven, centrifugal, Cramp's, engine room	2	7 & 14	2	12	...	...	...	...
Main feed	2	Piston, vertical, simplex, Blake, engine room	1	16	2½	18	1	10	2½	18
Auxiliary feed	4	Piston, vertical, simplex, Blake, firerooms	1	12	2¼	12	1	8	2¼	12
Hot-well	2	Piston, vertical, simplex, Blake, engine room	1	6	1 3/16	12	1	6	1 3/16	12
Fire and bilge	2	Piston, vertical, simplex, Blake, engine rooms	1	12	2¼	12	1	10	2¼	12
Auxiliary condenser	2	Simplex, combined air and circulating, Blake, engine room	1	6	1¼	10	1	10	1½	10
Dynamo condenser	2	Simplex, combined air and circulating, Blake, bunker space	1	10	1½	12	1	14	1¾	12
Evaporating and distilling plant		Distiller circulating	1	12	2¼	12	1	16	2¼	12
	1	Evaporator feed, Blake type	1	4½	1⅛	6	1	5	1⅛	6



MISSISSIPPI
ZATION RUNS
45
90

BOILERS.

There are eight Babcock & Wilcox boilers of the latest improved type arranged in four watertight compartments. These boilers are of the following dimensions:

Length, feet and inches	9-01¼
Width, external, feet and inches	16-05¼
Number of furnaces	2
Number of headers	24
Grate surface, one boiler, square feet	96
Heating surface, one boiler, square feet	4,081
Grates, length, feet and inches	7-00
width, feet and inches	6-10¼
Pressure, design, working, pounds	265
test, pounds	400
Ratio G. S. to H. S	42.5
Number of tubes, one boiler, 2-inch	754
4-inch	48
Length of tubes, as fitted, feet and inches	8-02

OFFICIAL TRIALS—*MISSISSIPPI*.

Standardization of Screws.—The vessel was tried by the standardized-screw method, progressive runs being made over the measured mile at the Delaware Breakwater October 16, 1907. From the data obtained on these runs the curves shown on Plate 1 were plotted.

It was determined that 120.45 revolutions per minute of the main engines would give the required true speed of 17 knots. The draught and corresponding displacement at the beginning and the end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	24-2⅝	24-0⅝
aft, feet and inches	25-2¼	25-0⅝
Displacement, tons	13,040	12,931

OFFICIAL FOUR-HOURS' TRIAL—*MISSISSIPPI*.

On October 17, 1907, the *Mississippi* got under way at the Delaware Breakwater and stood out to sea for the four-hours' full-power trial required by the contract. The weather was clear and pleasant. Calm to light breeze from West to South. Smooth sea. The draught and displacement at the beginning of the trial were as follows:

Forward, feet and inches	$24-3\frac{5}{8}$
Aft, feet and inches	$25-4\frac{1}{4}$
Mean, feet and inches	$24-9\frac{15}{16}$
Corresponding displacement, tons.	13,124

A synopsis of the data obtained on this four-hours' trial follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.
MISSISSIPPI.

	Starboard.	*Port.*
Steam Pressures. (Average of one-half hourly observations.)		
Mean steam pressure at engines, pounds	258.4	265.0
H.P. steam chest gauge, lbs.	246.2	243.75
1st receiver (abs.), pounds	109.0	103.9
2d receiver (abs.), pounds	29.4	22.15
Vacuum in condensers, inches of mercury, mean	25.5	26.4
Temperatures. (Average of one-half hourly observations.)		
Injection, degrees	59.6	59.0
Discharge, degrees	94.8	98.6
Hotwell, degrees	88.3	91.3
Feed water, degrees	192.8	197.0
Engine room, upper platform, degrees	100.0	100.0
working platform, degrees	89.4	96.4
Firerooms, working level, degrees	95.0	
Smoke stacks, average, degrees	617.0	
Revolutions, or double strokes, per minute. (Average of one-half hourly observations.)		
Average revolutions, main engines, per minute	122.06	122.01
Pumps, main air	22.2	19.8
circulating	177.0	195.4
feed, d. s., per minute	25.4	26.7
fire and bilge	48.0	27.3
Dynamo engines	350.0	
Blower engines	497.9	
Speed of ship, in knots per hour	17.11	
Slip of propeller, in per cent. of its own speed, based on mean pitch	16.45	16.42
Air pressure in firerooms, in inches of water, mean	1.36	
Mean Effective Pressures in Cylinders, in pounds per square inch. (Averages of cards taken at half-hourly periods.)		
Main engines, H.P. cylinder	99.3	92.6
I.P. cylinder	60.6	64.2
L.P. cylinder	25.0	24.7
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	60.49	60.73

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P. cylinder	1,459.5	1,361.0
I.P. cylinder	2,458.0	2,605.0
L.P. cylinder	2,750.5	2,726.0
Collective H.P. of both main engines	**13,361.0**	
Air pumps, main	33.0	
Circulating pumps, main	67.0	
Feed pumps, main	135.0	
Auxiliary feed pumps	11.0	
Fire and bilge pumps	18.0	
Forced-draft blowers	192.0	
Dynamo engines	83.0	
Collective I.H.P. main engines, air, circulating and feed pumps	**13,607.0**	
Collective, main and auxiliary engines, in operation	**13,900.0**	

COAL.

Kind and quality used on trial	Pocahontas hand picked.
Pounds, per hour, main and auxiliary engines, during trial	23,525.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	18.10
Pounds of coal per I.H.P. per hour, main engines only	1.761
all machinery in operation	1.692
square foot of grate surface, per hour	30.63
Cooling surface (main condenser) per I.H.P., main engine	1.042
Heating surface, square feet per I.H.P. (total)	2.35

TWENTY-FOUR HOURS' ENDURANCE TRIAL—*MISSISSIPPI*.

At 7:00 P. M., October 17, 1907, the twenty-four hours' endurance trial, under all boilers, as prescribed by the contract, was commenced. The weather was clear and pleasant, with gentle breezes from W. by S. The sea was smooth.

The data obtained on this trial were as follows:

PERFORMANCE—TWENTY-FOUR HOURS' OFFICIAL TRIAL.—*MISSISSIPPI*.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	241.7	
Mean steam pressure at engines, pounds	234.5	241.3
H.P. steam chest, gauge, pounds	186.2	178.1
1st receiver (absolute), pounds	52.1	51.8
2d receiver (absolute), pounds	9.71	9.67

Temperatures. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Injection, degrees	59.5	58.6
Discharge, degrees	106.3	104.4
Hotwell, degrees	83.9	80.8
Feed water, degrees	169.6	223.2
Engine room, working platform, degrees	83.4	80.9
Firerooms, working level, degrees	97.7	
Smoke stacks, average, degrees	445.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

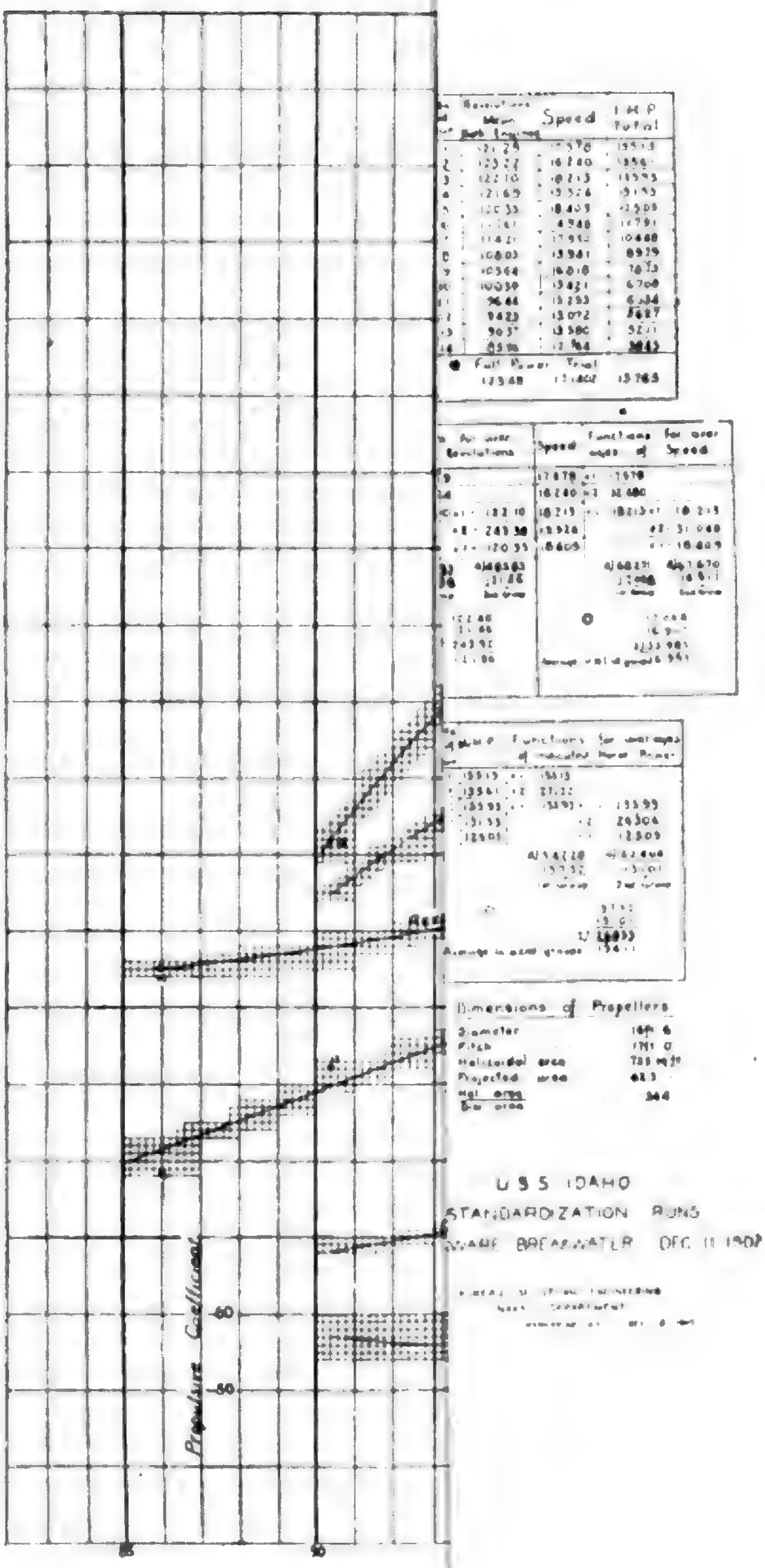
	Starboard.	Port.
Average revolutions, main engines, per minute	101.54	101.59
Pumps, main air	18.8	17.5
circulating	151.8	146.8
feed, d.s., per minute	20.8	8.4
fire and bilge	31.0	32.7
auxiliary feed	44.4	
Dynamo-engines	350.0	
Blower engines	280.7	
Speed of ship, in knots per hour	15.13	
Slip of propeller, in per cent. of its own speed, based on mean pitch	11.20	11.21
Air pressure in firerooms, in inches of water, mean	0.468	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

	Starboard.	Port.
Main engines, H.P. cylinder	103.5	93.1
I.P. cylinder	34.3	34.9
L.P. cylinder	13.14	13.72
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	40.65	38.96

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P. cylinder	1,287.0	1,136.0
I.P. cylinder	1,157.0	1,173.0
L.P. cylinder	1,207.0	1,255.0
total	3,651.0	3,564.0
Collective H.P. of both main engines	**7,215.0**	
Air pumps, main	34.0	
Circulating pumps, main	36.0	
Feed pumps, main	68.0	
Auxiliary feed pumps	12.0	
Fire and bilge pumps	12.0	
Forced-draft blowers	56.0	
Dynamo engines	83.0	
Collective I.H.P. main engines, air, circulating and feed pumps	**7,365.0**	
Collective, main and auxiliary engines in operation	**7,516.0**	


Speed
I.H.P. Total
Full Power Trial
Dimensions of Propellers
Diameter
Pitch
Projected area
U S S IDAHO
STANDARDIZATION RUNS
DEC 11 1907
Propulsive Coefficient
.60
.50

COAL.

Kind and quality used on trial.................... Georges' Creek, run of mine.

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface..........................	9.796
Cooling surface (main condenser), sq. ft., per I.H.P. (main engine)..	1.93
Heating surface, square feet per I.H.P. (total)	4.34

OFFICIAL TRIALS—*IDAHO*.

Standardization of Screws.—The vessel was tried by the standardized-screw method, progressive runs being made over the measured-mile course at the Delaware Breakwater, December 11, 1907. From the data obtained on these runs the curves indicated on Plate 2 were plotted. The weather was generally overcast, with stiff to fresh breeze from W.N.W., moderating somewhat toward the end. There was a moderate sea from W.N.W.

From the results of these runs, with and against the tide, it was determined that 121.86 revolutions per minute of the main engines would be required for a true speed of 17 knots, required by the contract. The draught and corresponding displacement at the beginning and the end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches..............................	24–4$\frac{3}{4}$	24–2$\frac{1}{2}$
aft, feet and inches......................................	25–8$\frac{1}{4}$	25–5$\frac{1}{8}$
Displacement, tons..	13,248	13,105

OFFICIAL FOUR-HOURS' TRIAL—*IDAHO*.

On December 12, 1907, the *Idaho* got under way at 6.30 A. M. for the official four-hours' trial, as prescribed by the contract. The weather was fair, with a stiff breeze from W.N.W. The sea was moderate at first, increasing to rough near the end of the trial. The draught and displacement at the beginning of the trial were as follows:

Forward, feet and inches.....	24–0$\frac{1}{4}$
Aft, feet and inches..	25–7
Mean, feet and inches..	24–9$\frac{1}{2}$
Corresponding displacement, tons...	13,093

The data obtained on the four-hours' trial were as follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.—*IDAHO*.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	278.0	
at engines, pounds	255.0	255.0
H.P. steam chest gauge, pounds	247.0	261.0
1st receiver (absolute), pounds	131.6	131.9
2d receiver (absolute), pounds	45.5	44.1
Vacuum in condensers, inches of mercury, mean	27.3	26.4

Temperatures. (Average of one-half hourly observations.)

Injection, degrees	48.9	50.2
Discharge, degrees	104.3	105.2
Hotwell, degrees	115.5	111.3
Feed water, degrees	208.2	199.6
Engine room, working platform, degrees	86.9	84.0
Firerooms, working level, degrees	85.5	
Smokestacks, average, degrees	65.2	

Revolutions, or double strokes, per minute. (Average of one-half hourly observations.)

Average revolutions, main engines, per minute	123.62	123.34
Pumps, main air	25.7	40.1
circulating	173.4	168.0
feed, d.s., per minute	25.6	32.4
fire and bilge	...	28.0
auxiliary feed	...	20.1
sanitary	...	10.4
Dynamo engines	350.0	
Blower engines	454.0	
Speed of ship, in knots per hour	17.14	
Slip of propeller, in per cent. of its own speed, based on mean pitch	17.35	17.16
Air pressure in firerooms, in inches of water, mean	0.93	

Mean Effective Pressures in Cylinders, in pounds per square inch. (Averages of cards taken at half-hourly periods.)

Main engine, H.P. cylinder	96.9	96.2
I.P. cylinder	62.8	62.9
L.P. cylinder	26.2	25.1
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	62.4	61.1

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P. cylinder	1,426.0	1,441.0
I.P. cylinder	2,583.0	2,579.0
L.P. cylinder	2,803.0	2,933.0
total	6,812.0	6,953.0
Collective H.P. of both main engines	**13,765.0**	
Air pumps, main	18.0	
Circulating pumps, main	52.0	
Feed pumps, main	150.0	
Auxiliary condenser, air and circulating pumps	5.0	
Fire and bilge pumps	4.0	
Auxiliary feed pumps	25.0	
Forced-draft blowers	168.0	
Dynamo engines	80.0	
Sanitary pumps	2.0	
Collective I.H.P. main engines, air, circulating and feed pumps	**14,010.0**	
Collective, main and auxiliary engines in operation	**14,269.0**	

COAL.

Kind and quality used on trial	Pocahontas, hand-picked.
Pounds per hour, main and auxiliary engines, during trial	27,100.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	18.59
Pounds of coal per I.H.P. per hour, main engines only	1.969
Pounds of coal per I.H.P. per hour, all machinery in operation	1.898
square foot of grate surface, per hour	35.29
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.035
Heating surface, square feet per I.H.P. (total)	2.287

TWENTY-FOUR HOURS' ENDURANCE TRIAL—*IDAHO*.

The official twenty-four hours' endurance trial, under all boilers, as prescribed by the contract, was commenced at 3.00 P. M., December 12, 1907. The weather was fair and pleasant, with moderate breezes from W.N.W. There was a moderate sea.

The data obtained on this trial were as follows:

PERFORMANCE.—TWENTY-FOUR HOURS' OFFICIAL TRIAL—*IDAHO.*

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Mean steam pressure at engines, pounds	245.2	252.3
H.P. steam chest, gauge, lbs.	202.2	209.3
1st receiver (abs.), pounds	66.8	71.4
2d receiver (abs.), pounds	27.9	21.3
Vacuum in condensers, inches of mercury, mean	27.9	28.2

Temperatures. (*Average of half-hourly observations.*)

Injection, degrees	46.6	46.9
Discharge, degrees	77.7	87.4
Hotwell, degrees	96.4	106.3
Feed water, degrees	204.8	208.4
Engine room, working platform, degrees	79.0	
Firerooms, working level, degrees	90.0	
Smoke stacks, average, degrees	525.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	104.06	104.06
Pumps, main air	24.2	24.2
circulating	153.0	156.0
feed, d.s., per minute	14.8	16.4
fire and bilge	22.0	27.6
auxiliary condenser, air and circulating	20.8	
Dynamo engines	350.0	
Blower engines	280.4	
Speed of ship, in knots per hour	15.14	
Slip of propeller, in per cent. of its own speed, based on mean pitch	13.72	13.72
Air pressure in firerooms, in inches of water, mean	0.4	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	109.6	106.1
I.P. cylinder	33.7	32.6
L.P. cylinder	13.0	13.0
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	40.1	39.0

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	1,378.0	1,330.0
I.P. cylinder	1,178.0	1,135.0
L.P. cylinder	1,228.0	1,227.0
total	3,784.0	3,692.0

Collective H.P. of both main engines	**7,476.0**
Air pumps, main	14.0
Circulating pumps, main	29.0
Feed pumps, main	58.0
Auxiliary condenser, air and circulating pumps	4.0
Fire and bilge pumps	3.0
Forced-draft blowers	62.0
Dynamo engines	121.0
Sanitary pumps	1.0
Collective I.H.P. main engines, air, circulating and feed pumps	**7,577.0**
Collective, main and auxiliary engines in operation	**7,768.0**

COAL.

Kind and quality used on trial....................Mixed, run of mine.

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	11.48
Cooling surface (main condenser), sq. ft., per I.H.P. (main engine)	1.862
Heating surface, square feet per I. H.P. (total)	4.19

FEATURES OF A BATTLESHIP DESIGN.

By Lieutenant H. C. Dinger, U. S. Navy, Member.

As the subject of the design of new battleships, especially the design of the new all big-gun 20,000-ton battleship for the U. S. and foreign navies, is a matter very much discussed, I have thought that the setting forth of some important features that might be obtained in a new ship, and illustrating these by means of rough-sketch plans drawn approximately to scale, might be of considerable interest. It might also serve to call attention to certain important features which it might be advantageous to incorporate into new designs, and which have, in many cases, not been realized to the fullest extent.

The sketch plans are not complete, nor are they intended to be so. They are merely a rough and approximate outline upon which a detailed design could be based, and are intended to show ideas of general characteristics which might be modified or elaborated upon in various directions.

The aim of this paper has been to bring up certain new possibilities and to create discussion and service criticism of various features that should be embodied in the best possible fighting vessel that can be built on a displacement of less than 20,000 tons.

Some of the primary matters that should influence the design are:

To obtain everything with the least weight and space essential to the best possible operation and utility.

To arrange everything so that it can be operated and taken care of by the least possible personnel, both in officers and men.

To arrange everything so that all operations, work, etc., done, can be accomplished with the least possible labor.

To discard everything that is not definitely in a large measure essential to the fighting capacity, power and utility in time of war.

To make all parts as easy and cheap of manufacture as it is possible, while not detracting from their efficiency or adaptability.

To give to each item weight, space and other considerations in a proper proportion to their relative value as contributors to the total fighting power.

To make everything as simple as possible.

The target displayed in broadside should be as low as possible, and all top hamper that will, when struck, cause shell to explode, should be reduced to the very lowest possible limit.

All guns should be placed in such positions that they can be fought in any kind of weather.

The forecastle of the vessel should be sufficiently high to prevent seas from coming on board at high speeds or in rough weather.

QUESTION OF SPEED *VERSUS* BATTERY.

Speed is a valuable quality for offense and for defense, but its value is problematical; in some cases it may be of great use, in others of but little. Battery power is of certain and definite value and always has a definite utility. In fleet actions the speed of the combined fleet will not be very high, nor is it necessary. When speed will be wanted it will be needed to concentrate on certain parts of the enemy or to pursue an enemy. This can be accomplished by having a portion of the fleet of high speed. The problem then seems best to be solved by having a larger portion of the battleships of the fleet of moderate speed, say not over 18 or 19 knots, and of large battery power and ammunition supply; and then, also, to have a smaller proportion of high-speed battle-

ships of same protection, but with less battery power (though guns are to be of same caliber), less ammunition and less coal. These faster vessels would be preferable as flagships.

CHARACTERISTICS OF MODERATE-SPEED BATTLESHIPS.

We will first take up the requirements of the moderate-speed battleship. It may be assumed that the displacement will be 17,000 to 18,000 tons, and with this displacement the following general distribution of weight might be made:

	Tons.	Full load.
Hull and fittings	6,200	
Armor	3,800	
Protective deck	800	
Machinery, including water	1,800	
Battery and ammunition	1,800	2,000
Equipment	1,000	
Coal, normal	2,000	2,500
Total	17,400	18,100
Length, feet		490
Beam, feet		82
Draught, feet		25-26
I.H.P.		20,000
Speed, knots		18.5 to 19

As excessive speed is not necessary and as it costs too much to obtain it, a speed equal to or slightly in excess of that of our existing battleships is sufficient. All possible power that can be obtained on a certain allotment of weight should be secured, and the machinery should be the most economical in coal consumption that it is possible to secure.

It is perhaps possible by great care in design, especially with regard to matters tending to the highest possible economy in steam consumption, to secure machinery on 1,800 tons' weight that will enable this vessel to obtain a speed of twenty knots. It may also be remarked that although the turbine engines of the *Dreadnought* show a considerable advantage in economy at high speeds over existing vessels of our Navy, it is quite possible to build reciprocating engines that will be more economical than the turbine engines have shown themselves to be. The water consumption of 14 pounds of water

per indicated horsepower per hour can be equaled and even beaten by reciprocating engines when they are built so that they will utilize more nearly all means tending to economy which are now known to be practical for marine work.

BATTERY ARRANGEMENT.

The latest opinion of the best informed is that the main battery should consist of the greatest number of the heaviest guns that the vessel can carry. Assuming that the displacement is 17,000 to 18,000 tons, the weight that can be allotted to the battery will be something below 2,000 tons. A battery of ten 12-inch guns can be installed on about 1,500 tons. If we allow 300 tons for a battery of rapid-fire guns the total weight of battery can be set at 1,800 tons.

The arrangement adopted for the *Michigan* for four two-gun turrets on centerline gives the best possible arc of fire for these eight guns. Having placed eight of the guns in this way, positions for the other two guns must be found. If they are placed in two turrets, one on each side, as on *Dreadnought*, these guns can have an arc of fire of 180 degrees, but all of the large guns cannot fire on either broadside. A fifth turret can be placed on centerline, and with this arrangement all of the heavy guns can fire on either broadside, and by arranging the superstructure properly the after guns will be able to fire within a few degrees of dead ahead.

With the arrangement shown on sketch plan, we will have a fire of ten 12-inch guns on each broadside, and to about 20 degrees from ahead, and four 12-inch directly ahead or astern. The 12-inch guns will be placed at such commanding heights that no difficulties in rough weather need be feared.

The secondary battery should consist of a limited number of 5-inch guns, about ten. These guns would be for primary use in action against the unprotected parts of the enemy and, in combination with a few smaller saluting guns located under the forecastle, against torpedo attack.

These 5-inch guns should be of the greatest range and

muzzle velocity that can be attained with this caliber; and their mounts should have all possible attachments for securing great rapidity and accuracy of fire. They should either be well protected by armor that will keep out splinters and which cannot be penetrated by the secondary battery of a possible enemy, or they should be unarmored.

There is some question as to the advisability of providing armor for the secondary battery. Some very weighty opinion is against using any armor for the secondary battery. If any armor is fitted it should be at least 5 inches thick. The fitting of light armor, 2 or 3 inches, is generally objectionable. If the armor for the secondary battery is left off, the weight, about 400 tons, can be utilized for other purposes. The main belt could be increased over an inch in thickness with this weight. The guns should be installed so that they all have great arcs of fire and so that all can be fired in rough weather.

In deciding upon the battery, the aim should be to get in as many guns as can be carried on the weight and to secure for each of these guns a maximum arc of fire. If the increase in number decreases the arc of fire of any of them to a considerable extent, then fewer guns should be installed.

In arranging the battery on this design it has been the aim to secure the very greatest arc of fire for every large gun installed. As arranged, each 12-inch gun will have an arc of fire of about 300 degrees, and all 12-inch guns can fire through an angle of about 120 degrees on either beam. The 5-inch guns are arranged so that at least three out of the nine can fire in any direction, and six can fire on either beam. They all have an arc of fire of about 130 degrees. They are arranged in two groups, so as to facilitate their fire control, ammunition supply and protection. The ammunition for all the guns is supplied directly from the magazine-handling room to the gun or gun-handling room, and requires no double handling. This is a most important matter in connection with the rapidity with which ammunition can be supplied.

It does not appear advisable to increase the number of large guns beyond ten. If more are added they would have to be placed on one side of the ship and their arc of fire would be decreased. To secure room for another turret on the center line, the vessel would have to be lengthened to such an extent that the displacement would be materially increased.

MACHINERY.

If reciprocating engines are used the machinery should consist of two 4-cyl. triple-expansion engines, $\frac{32'' \times 50'' \times \text{two } 75''}{48''}$ designed to work with 275 pounds of steam at throttle and give about 20,000 I.H.P. Special provision should be made to have the engine clearances reduced as much as possible and to have large L.P. exhaust pipes and ample condensing surface so that a good vacuum may be obtained in the L.P. cylinder when running at full power. Feed-water heaters specially arranged to secure the highest feed temperature from the auxiliary exhaust steam should be fitted. There should be twelve water-tube boilers having about 1,200 square feet of grate surface. Boilers to be fitted with superheaters. Forced-draft blowers, with electric drive, capable of producing an air pressure of three inches of water, should be supplied, and these should be located on the deck above the boiler rooms, but arranged so that the speed can be regulated from the fire-room. The main feed pumps should be located in the engine rooms, and should be fitted with steam-regulating valves for automatically keeping a constant excess pressure in the feed line. Ash ejectors should be provided. Extraordinary measures should be taken to provide the greatest possible ease and facility for operating and overhauling all machinery. If sufficient data has been obtained concerning the economy and reliability of steam turbines to prove their superiority over naval reciprocating engines of the present date, then turbines should be installed. If they are installed it should be with the idea that they are to be the motive power for all battleships built in the immediate future. The superior advantages

should, however, first be proven to compensate for the sacrifice presented in a lack of uniformity and the use of machinery unfamiliar to the present naval personnel. It might be advisable to install a combination of turbines and reciprocating engines on three screws. The center screw would have a turbine of about half total power and the two wing screws would have reciprocating engines. Such a combination would probably lead to greater economy at cruising speeds than the all-turbine arrangement.

COALING.

Some changes ought to be made from our present arrangements for coaling, and in arranging the bunkers for supplying coal to the fires. The coal must be capable of being taken on board rapidly, and it should be possible to cart it quickly from one chute to another. It should be possible to coal without interfering with the battery or the living quarters of the crew. One of the most serious defects in some late U. S. battleships is the coaling arrangement. Coal must be hoisted above the boat deck and then lowered through hatches to the linoleum-covered gun deck, on which are located the 7-inch guns, each separated by an armored bulkhead. On this deck the coal is put into chutes which lead to the bunkers. During the period of coaling the men having quarters on the gun deck have no place to eat and sleep, and in cold weather this is a serious matter. Also, while coaling and for several hours after, until things can be cleaned up, the guns on the gun deck are not ready for use.

The bunkers must be arranged so that there is about the same amount of coal available for each boiler. On some recent vessels the forward boilers are accessible to coal for only about two days' steaming, while abreast others there is an abundance.

The coal from the upper bunkers should be capable of being sent to the fireroom without opening the lower bunkers. This is provided for in the latest designs by having chutes leading from the upper bunkers and opening into the

firerooms. By this arrangement the lower bunkers can be kept closed in action. This ensures better protection against damage by torpedoes. By using coal from above the protective deck the stability of the vessel is maintained in better shape.

In the sketch plan it will be seen that there are five double lower bunkers on each side and six upper single bunkers on each side, making thirty-two bunkers in all. Each group of main bunkers will have two permanent filling chutes which extend to the main deck, there being portable chutes between upper and berth decks. These chutes should be amply large, at least two feet in diameter. By this arrangement of coaling, the coal can be put into the bunkers with the least possible disturbance to other parts of the ship. The crew's quarters and battery is in no way interfered with, and there is ample room at the openings to handle and dump the bags or buckets in which the coal is hoisted.

WATERTIGHT SUBDIVISION.

The latest practice is to provide no doors whatever in the transverse bulkheads between the several boiler rooms and engine room. In order to get from one compartment to another it is necessary to go up about 30 feet through various decks and then down again. Under these conditions it is impossible to have proper supervision of the machinery, and dangerous accidents are very likely to occur. These boxed-in engineer departments will have a terrible time when maneuvering in squadron at anything near full power.

The latest types of watertight doors are quite reliable, and the need of decent communication between the various parts of the engineer department is so great and all-important that the prohibition of all doors in transverse bulkheads probably creates greater defects than the one it is designed to remedy. The extreme importance of being able to manipulate the machinery of a naval vessel with facility and exactness is, I fear, somewhat overlooked in the design which contemplates the omission of doors. The idea seems to be to get machinery of

a certain power in somehow. Matters that affect the possibility of it being readily handled too often receive only casual attention. If the machinery is installed so that it can be operated and overhauled with ease, full power and efficient service can be relied upon, but if installed so as to be difficult to operate it cannot be depended upon and the best results will not be obtained.

CONNING TOWER.

The present conning towers are so small, cramped and crowded with all manner of instruments, that in battle they would be practically useless for the purpose for which they are intended, namely, to furnish an armored position from which the commanding and navigating officer can observe and give directions for the handling of the ship in action. The conning tower should consist of an armored tube 12 to 15 feet in diameter, its base to be protected by armor from the protective deck up, and it should extend to a height of 6 or 7 feet above the highest mounted turret. The top of the tower should be open, and the first interior platform should be about 5 feet below the upper edge of the tower. There should be other platforms below, arranged at convenient heights, and on these and in the armored compartments about the base of the tower should be installed, in suitable groups with reference to each other, the wheel, engine telegraph, helm indicator, battle-order and range transmitters, voice tubes, telephones, apparatus for making signals, wireless station, etc.

Directions given by the commanding, navigating or fire-control officer could be passed to the operators stationed below by word of mouth or by telephone. The instruments of transmission and the operators would be thoroughly protected, and the directing personnel could remain on the upper platforms of the tower and be well protected yet capable of observing all parts of the vessel and have a clear view in any direction. All charts, diagrams, plans, etc., that are likely to be used during action should be accessible to the commanding, navigating and ordnance officers. Hence a portion of the space should be arranged for the convenient filing of such informa-

tion, which would consist of charts and navigating instruments, tactical information, information concerning enemies' vessels, gunnery instructions and ordnance data and any other information likely to be consulted during action.

A light bridge, supported by a metal frame, could be built out on either side of the tower. This could be utilized when specially needed, as in handling the ship alongside the dock. It is extremely important to cut down the enormous amount of top hamper that is being gathered around the bridge and conning tower of our late battleships. This great amount of truck, a great deal of which is inflammable, is an invitation to disaster in time of battle.

POSITIONS FOR RANGE-FINDING STATION AND STATIONS FOR FIRE-CONTROL OFFICERS.

This is a subject widely discussed by officers serving on armored vessels. Opinions differ very widely as to details, but all agree that special provision is necessary for these matters, and it should be embodied in the design of new vessels.

It would seem that the range-finding stations should be in an elevated position, and in one that had at least some protection. On present vessels range finders are mounted in tops without any protection. The range finders might be placed in elevated, small, armored casemates 10 or 12 feet in diameter, having armor several inches thick. The casemates should be supported by a skeleton framing stiff enough to prevent excessive vibration and designed so that a large part of the support could be shot away and still keep the range tower standing. Such towers would furnish about the nearest thing that our present knowledge would indicate to fulfill the requirements of a range-finding station.

The fire-control officers could have their stations in the same armored top, their directions to be sent by portable telephone or voice-tube system, either direct to the battery or to an operator placed in a well protected position below; this operator to communicate directions from fire-control officers to the battery.

In order to provide an alternate armored position for the fire-control officers in a position different from that of the range finders or that from which the ship is handled, an after armored tower might be fitted.

This tower could be arranged in a similar manner as the conning tower forward, but it could be smaller. From it would be operated such instruments of transmission as are necessary for communication between the fire-control officer and the battery.

In case the fire-control officers are stationed in the tops, this after tower could be used as an observation tower, or as a place from where the vessel might be directed in case an unlucky shot or explosion should wreck the forward tower. The principal instruments necessary for the handling of the vessel could be duplicated in the after tower.

To avoid the danger of having splinters from the supports of the mast falling on top of the armored tower it would be more advantageous to move the masts some distance from the conning tower, as shown in sketch plan, than to have these masts directly over the bridge and conning tower, as has been the practice in most battleships.

The arrangements for communicating from the fire-control officers to the battery must be separate and distinct from the system of general communication throughout the ship. The exact details of this system will, however, depend upon the system of fire control that is developed and adopted. In order that certain important structural matters may be arranged for this purpose, it is necessary to know definitely the general essential features of the fire-control system to be used. When the basic principles and elementary matters as to the method of handling the ship in battle is definitely decided upon, then all structural matters, to carry this out, should be furnished, and the development of these arrangements should not be compromised by the interference of other matters that are not as essential to the fighting efficiency.

If a height of about 65 feet is considered a sufficient elevation, the best position for the range-finding station would

seem to be just forward and abaft the smoke stacks and about 10 feet below the level of the top of stack. In this position the interference from smoke is done away with. If the stations are located at a height just above the top of the smoke stacks, smoke will interfere at some time or another, especially in action, when courses are frequently changed and forced draft is being used.

If, on the other hand, it is found necessary to have the range-finding and fire-control station at a higher elevation, say 100 feet above water line, then this station will have to be raised and the smoke stacks shortened so that their tops are at least 25 feet below the fire-control station.

In the sketch plan, sheets 1 and 2, the two positions for fire-control station are shown. In case the high station, shown in dotted lines, is used, the tops of smoke stacks would reach only to O.

ARMOR.

The purposes of armor may be divided as follows: (1) To protect the heavy gun positions. (2) To protect the magazines and ship's vitals. (3) To protect the vessel's flotation by keeping the water line intact. (4) To protect the secondary battery and other important equipment about the decks. (5) To protect the directing personnel in battle.

The heavy guns are protected by heavy turrets and barbettes; armor 12 to 9 inches thick is proposed. The vitals are protected by the protective deck and by the side armor. The armor to protect the water line, and thus the floating power of the vessel, should be a complete belt, thick enough and extensive enough to prevent any dangerous puncture at or near the water line. If it is not a complete belt its efficiency is seriously impaired, since a shell striking the unarmored part will at once destroy the integrity of the water line.

For these reasons the water-line belt should be complete. Forward and aft it can be made slightly thinner than amidships. Armor 10 inches thick is contemplated for the thick-

est part of the belt, to be thinned to 6 inches at bow and stern. The belt should be about 12 feet high, the part extending below the water line to a distance of 4 feet can be gradually thinned to 6 inches. With this arrangement the upper edge of belt will be about 7 feet above the water line when ship is fully loaded. When light, the lower edge of belt will be about 2½ feet below water line. If the belt is too high it can always be lowered by filling some of the double bottom compartments; so that it is more advisable to have the belt too high than too low.

The armor for protecting the secondary battery, if fitted, is to form a casemate around the 5-inch guns, as shown, and be 6 inches thick. This armor not only protects the secondary battery, but also to a great extent the ventilators, smoke-stacks, blowers and other equipment located on main and berth deck. For 320 feet amidships the main belt will have a maximum thickness of 10–11 inches. At the ends of this armor there will be diagonal armor 8 inches thick connecting the side armor to the barbettes of the forward and after turret. Forward and aft of the magazines the armor will be 6 inches thick. The belt will extend to the level of the berth deck, which will be armored.

Each smoke stack is to be individually protected by 6-inch armor, as shown, to extend from berth deck to above boat deck. The space between this armor and the smoke stack proper is to be utilized as an air shaft for ventilating the orlop-deck passage and as a means of supplying air to those forced-draft blowers that are located on the center line. The purpose of this armor about the smoke stack is to guard against shells piercing the base of stack or exploding there. This armor will insure a certain amount of natural draft for the fires, and will also guard against the disastrous results of having the smoke from the boilers coming on to the various closed decks of the vessel, which is what will happen when the base of an unarmored stack is pierced by a shell or fragment.

Smoke stacks should also be made in bolted and flanged

sections, so that in case they are struck, they will break at the section and not, as was the case with many Russian ships, bring down the whole stack.

The armored conning tower is to have 8-inch armor from the level of the 5-inch gun casemate to the top. Diagonal armor is to be fitted at the forward ends of forward 5-inch gun casemate to protect the various decks from a raking fire from forward.

To protect against under-water damage by torpedoes, an extra longitudinal bulkhead is worked in on each side, separating the inboard and outboard coal bunkers. This bulkhead should be extra strong so as to be able to withstand the shock of an explosion. The outboard bunkers would be filled through a chute at the top and emptied through doors opening into inboard bunkers. In action these doors would be kept closed, and outboard bunkers preferably full of coal. The corresponding compartments on opposite sides of the vessel should be connected by pipes to enable the vessel to be kept upright in case a large compartment on one side is damaged.

PROTECTIVE DECK.

The protective deck should protect from a plunging fire and from splinters and fragments. It would appear that the proper place for the armored deck would be at the upper level of the armor belt. As shown in plans, the armored deck in connection with the side armor forms an armored box which primarily protects the water line, and guards against any punctures that would tend to destroy or injure the vessel's floating power. It also protects the machinery and magazines from shells. At the water line there is a curved watertight deck, which is primarily for strength and subdivision, but also serves as a splinter deck.

It is believed that this arrangement of armored decks offers better protection than where there is an armored deck at the level of the bottom of the armored belt. The armored deck, as arranged, will stop the effect of plunging shot one deck height sooner, and the lower watertight deck will serve to

catch any splinters or fragments. The arrangement also gives a greater and more extensive protection to the machinery and the magazines.

ARMORED POSITION FOR WOUNDED IN BATTLE.—OPERATING ROOM BEHIND ARMOR.

Most vessels built are not provided with a well-protected place where the wounded in action may be placed and looked out for. Operating rooms are very often in unprotected parts of the ship that would become uninhabitable in a close action. In the sketch design it will be noticed that the operating room is behind thick armor, and a portion of the sick bay is also behind armor.

On the center line, immediately above the curved watertight deck, well protected by armor and also by coal bunkers, there is a wide passage which contains the forced-draft blowers. The smoke stacks run through the center, and the boiler-room hatches and ventilators are at the side. This space is to be fitted up, where available, with tiers of bunks. Under ordinary circumstances this is to be the berthing space for the firemen. Here the firemen, coming off watch, may be able to get some needed rest in peace and quiet—a matter quite essential to securing an efficient fireroom force. In time of battle it will be a good place to bring the wounded to, and it will be convenient to the operating room. This space can be well ventilated, since there are plenty of hatches running through it, and it will be no hotter than the ordinary berth deck. From this space can be operated all the boiler-room valve-lifting gear, such as for boiler-stop and safety valves, main drain, fire-main and fire-extinguishing valves. This gear in many of the present vessels is placed so that it interferes with the handling of the battery. From this space communication with any boiler room, engine room, evaporator room or machine shop is readily secured, and it forms a thoroughly-protected passage from one end of the ship to the other. Voice tubes, electric mains, etc., can be led through this space and be kept in accessible positions.

CLEAR SIDES AND UPPER DECKS.

As will be seen, the main deck will be clear of all obstructions from the ship's side to the deck houses located on the center line, which contain offices aft, boat and deck stores, tanks for oils, galleys, bakery and bread room in the center, and blacksmith shop and laundry forward. In action this deck can be kept well clear, the only guns mounted on it are the 5-inch well forward. The clear deck gives a good open space as a lounging place for the men, enables a better supervision over the crew to be obtained, gives a good place for conducting drills and the very best facilities for handling lines or boats, getting on stores, etc. It makes one end of the ship accessible to the other. Around the sides of the deck houses could be located hammock nettings and small lockers for deck gear and fittings.

STORE ROOMS.

One of the most laborious jobs on board ship is the getting in and out and the shifting of stores. The arrangement and location of the storerooms will materially affect the amount of this work. Storerooms are often put in any old place left over from other uses. A thorough investigation of the uses to which various storerooms are put, and an effort to put them where they will best serve their purposes, would bear startling results in increased ease in handling and keeping stores and increased capacity for stowing them. When a ship is designed the question of the location and arrangement of storerooms must be considered. Storerooms must be located so as to secure the least handling of the matters that are to be stored in them. Storerooms that are being constantly used should be in accessible positions, and the best possible facilities for getting the stores in and out should be provided.

In the sketch plans an attempt has been made to indicate, in a general way, the location of the principal storerooms in the most convenient places for their use. It will be noticed that the bread and flour rooms are near the bakery, provisions are near the pantries and galleys where they will be used.

Boat stores, blocks, tackles, lines, cordage, etc., are provided on the upper deck near where these matters are to be used. Engineer and electrical storerooms are arranged so as to be handy to the engineer department and dynamo room. The main engineer storerooms are accessible to both the engine and the fireroom. The gear and stores for engineer and dynamo storerooms, machine shop and evaporator room can be lowered down the engine hatch. In the forward and after part of the vessel the space between the berth and orlop deck, 7 to 9 feet high, is available for stores. This space is accessible through hatches in the berth deck.

There should be certain storage spaces arranged so that different character of stores could be carried in them at various times. Thus they could be arranged so that they would be available for either coal, ammunition or provisions, and they could then be used for whichever article was the most important to carry at any one time. At certain times it may be extremely necessary to carry an extra supply of ammunition, at other times extra stores, and again it may be an extra amount of coal that is most needed. In the sketch design it is contemplated that the large bunker spaces abreast the engine rooms and the forward dynamo room may, when occasion demands, be utilized either for magazines or stores.

GALLEY, PANTRY, ETC.

The best location for the galley and bakery is naturally on the upper deck, where the fumes of cooking and baking and the unpacking of boxes of provisions and the handling of other culinary gear will interfere the least with the living quarters and the battery.

The pantry should be on the deck having the crew's messes, and it is suggested that the pantry, and not the galley, be made the serving-out place. As arranged in sketch plan the pantry is directly under the galley, and dumb waiters should be fitted connecting the two. In order that hot drinks and certain other dishes may be kept warm after they have been served out to messmen, there should be a number of small

electric heaters about the mess deck upon which the food after leaving the pantry could be kept warm until the time it is to be eaten. It is contemplated that all the crew messing will be on the same deck as the pantry, which fact should tend to facilitate and improve the serving of the food.

Adjacent to the galley there should be lockers or small store rooms, where culinary supplies, in constant use at the galley, should be kept and stored. This should include a great many dry and wet provisions, which are now generally kept in holds or storerooms beneath the protective deck and which require a great deal of time and trouble to break out. There should also be a space fitted up as a butcher shop where the meat could be cut and prepared for cooking. Sufficient space for these accessories could be found in the spaces assigned the galleys and bakery in the sketch plan.

COLD STORAGE AND REFRIGERATORS.

A great improvement in these matters would be effected if a portion of the cooling chambers were arranged as ready or thawing rooms, where meat and provisions about to be used could be kept and drawn from as needed. The main storage rooms would only be entered once a day or once in two days, a certain supply of meat, etc., taken out and then placed in the ready rooms, from where it can be taken as needed. The fitting of these ready rooms would allow a great many of the large portable ice chests, now supplied, to be discarded.

In the sketch plan such ready-refrigerating rooms are indicated on the berth deck forward, near the scuttle butts, immediately above the ice machines. The location is convenient to both the pantry and the galley. Trap doors should be fitted through berth deck into refrigerating chambers so that they could be filled through these, instead of fetching it below and putting the large pieces of meat through small side doors. Much closer stowage would be possible in this way.

WINCHES AND BOAT BOOMS.

Winch and crane machinery should be reduced as much as possible, and where possible should be placed where it might be protected by armor. In many of the present designs all the boat and crane motors are in very much exposed positions on the upper and bridge deck. In any close action these machines would not only be dismembered by shell, but the fragments from the machines are likely to cause serious damage to the surrounding personnel and equipment and the guns of the secondary battery. It is possible to arrange it so that the crane motors and many of the coaling hoists can be located lower down, where the splintering effect would be less. .Some of these machines might be placed behind armor. A portion of the coaling hoists should be made portable and arranged so as to be temporarily secured to the deck where-ever the special conditions of coaling would secure the best leads. If this were done, the number of coaling hoists fitted on board might be reduced to some extent. When the vessel is cleared for action such portable hoists could be placed in a position where they are not likely to interfere with the battery or the personnel. It would be a military advantage to dispense with the turntable type of boat crane now in use, and install instead boom derricks supported from the masts. The lines could be handled by certain winches, which, like the booms, could also be used for coaling. By doing this a great deal of top-hamper and shell-catching gear might be avoided without any loss in working efficiency.

SEARCHLIGHTS.

The searchlights can be mounted in the upper tops of the masts, or on platforms on the skeleton masts. They could be fitted with electric controlling gear so that they can be operated from below. It might also be an advantage to have arrangements provided whereby they could be lowered in the day time in case an action is likely, and hoisted to their position at night. This would greatly lessen their chances of

being shot away. To work in combination with these elevated searchlights there should be portable searchlights mounted on specially designed carriages, which could be moved to any desired position on the main deck and operated from there. This would seem to be the solution of the searchlight problem.

HIGH-SPEED BATTLESHIP.

To secure a high-speed battleship the allotment of weight will have to be modified so as to get more weight for machinery. This can be done only by cutting down proportionately on something else. The principal weights that may be reduced are the battery, ammunition and coal. Some slight reduction may be possible in equipment weights. On a weight of 2,500 tons, machinery capable of developing 35,000 I.H.P. can be built. To get this weight the following allotment might be made.

	Tons.	Full load.
Hull and fittings	6,400	
Armor	3,800	
Protective deck	800	
Machinery, including water	2,500	
Battery and ammunition	1,300	1,500
Equipment	900	
Coal, normal	1,600	2,200
Total	17,300	18,100
Length, feet		510
Beam, feet		80
Draught, feet		25–26
I.H.P.		35,000
Speed, knots		24 to 25

This would call for a reduction in main battery to eight 12-inch guns and a considerable reduction in ammunition and coal. The speed would be from 24 to 25 knots. The lines of the vessel would be finer, the length greater and the beam slightly less. The removal of the middle turret would allow for the increased space necessary for the machinery. The increase in boiler power would require sixteen boilers, making it necessary to have another boiler room and smoke stack.

The decrease in beam would reduce the bunker space, as would also the increase in width of boiler room necessary to accommodate larger boilers.

The armor should be arranged in the same manner and be of the same character and thickness.

Such a fast battleship would have the same resisting power and her battery would have the same range as that of the other battleship. There would simply be an exchange of additional battery for speed.

This vessel could be used to bring an enemy into an engagement, to concentrate on a weak point, to pursue a fleeing enemy, and in general to utilize whatever advantages the possession of speed might at any time have. Vessels of this character, in the proportion of one to four for the total number of battleships, would seem to be a real, sound compromise between speed and gun power.

These vessels would differ from the present armored cruiser in that they have the same armor protection and hence a resisting power equal to that of a battleship. They have the same caliber and range for their big guns as the ordinary battleship, and hence can engage at the same range as the battleships. They are thus in every way qualified to take their position in the fighting line.

BATTLESHIP WITH HEAVIER GUNS.

Another matter for consideration in the design of the best type of battleship is the question of whether it is advisable to use a gun larger than the 12-inch for the main battery.

There are some who advocate the use of larger-caliber guns, 13 or 14-inch of 40 or 45 calibers in length. The advantage that these guns will have is the increased range and increased power of penetration at long ranges. It is argued that the ships armed with these heavier guns would be able to knock out the vessel armed with the 12-inch gun before the latter could get within effective range. Of course, the use of the larger gun would mean a reduction in number and also some reduction in rapidity of fire.

No high-powered guns of these larger calibers have as yet been built for naval work; but, of course, that does not mean that they cannot be built. There would, however, probably have to be considerable experimenting before a thoroughly successful large gun would be developed.

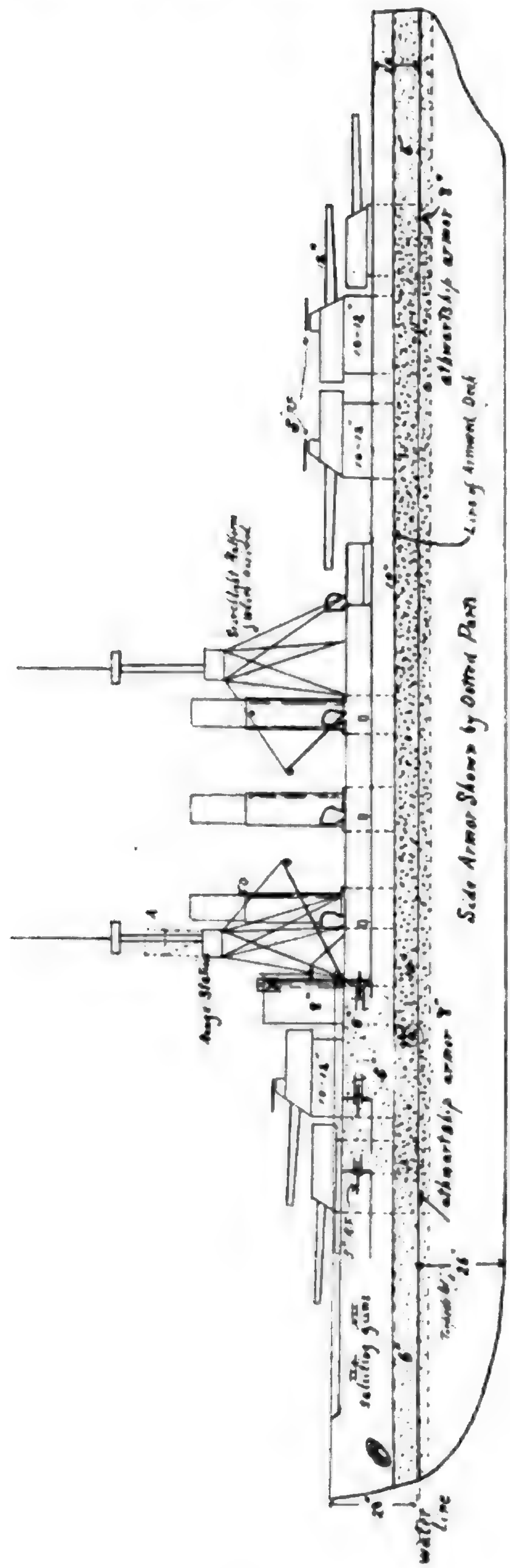
If it should be considered more advisable to use 13 or 14-inch guns, the arrangement of battery suggested would be eight guns in four turrets on the center line, placed in same general positions as on sketch plan, sheet 6. The general arrangement of vessel and secondary battery would be approximately the same as shown for the design with 12-inch guns.

Granting that the larger-caliber gun will weigh 30 per cent. more than the 12-inch, eight of the larger guns, with their ammunition, can be installed on 1,500 tons weight. The four turrets will weigh about the same as the five smaller turrets. The armor and structure of the ship would be about the same as before.

A fast battleship, with the larger-caliber guns and same displacement, would have six guns mounted in three turrets, one forward and two aft. Six guns with ammunition can be installed on 1,300 tons. This would allow 2,600 tons weight to be allowed to machinery.

On the other hand, a fast battleship could be built to carry eight of the larger guns by an increase of about 15 per cent. in the displacement, which would allow an approximate distribution of weights, as follows:

	Tons.
Hull	7,500
Armor	4,000
Protective deck	1,000
Machinery	2,800
Equipment	1,000
Battery and ammunition	1,800
Coal, normal	2,000
Total	20,100

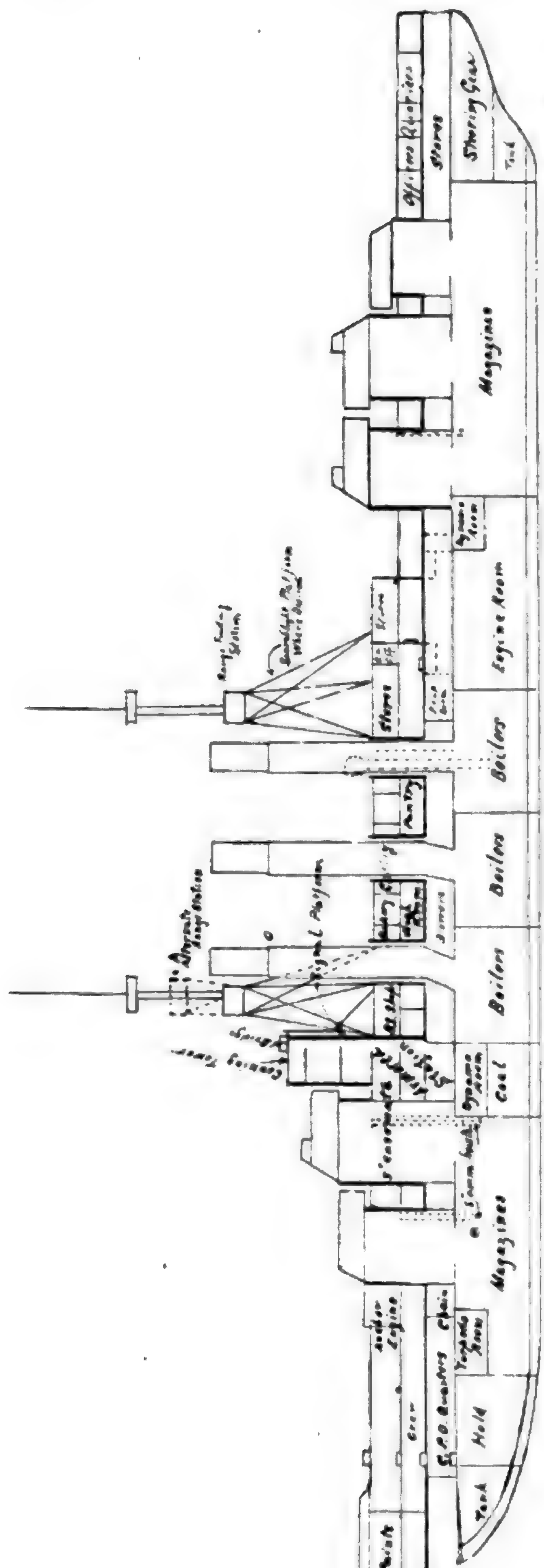


OUTBOARD PROFILE.

Scale 1" = 80'.

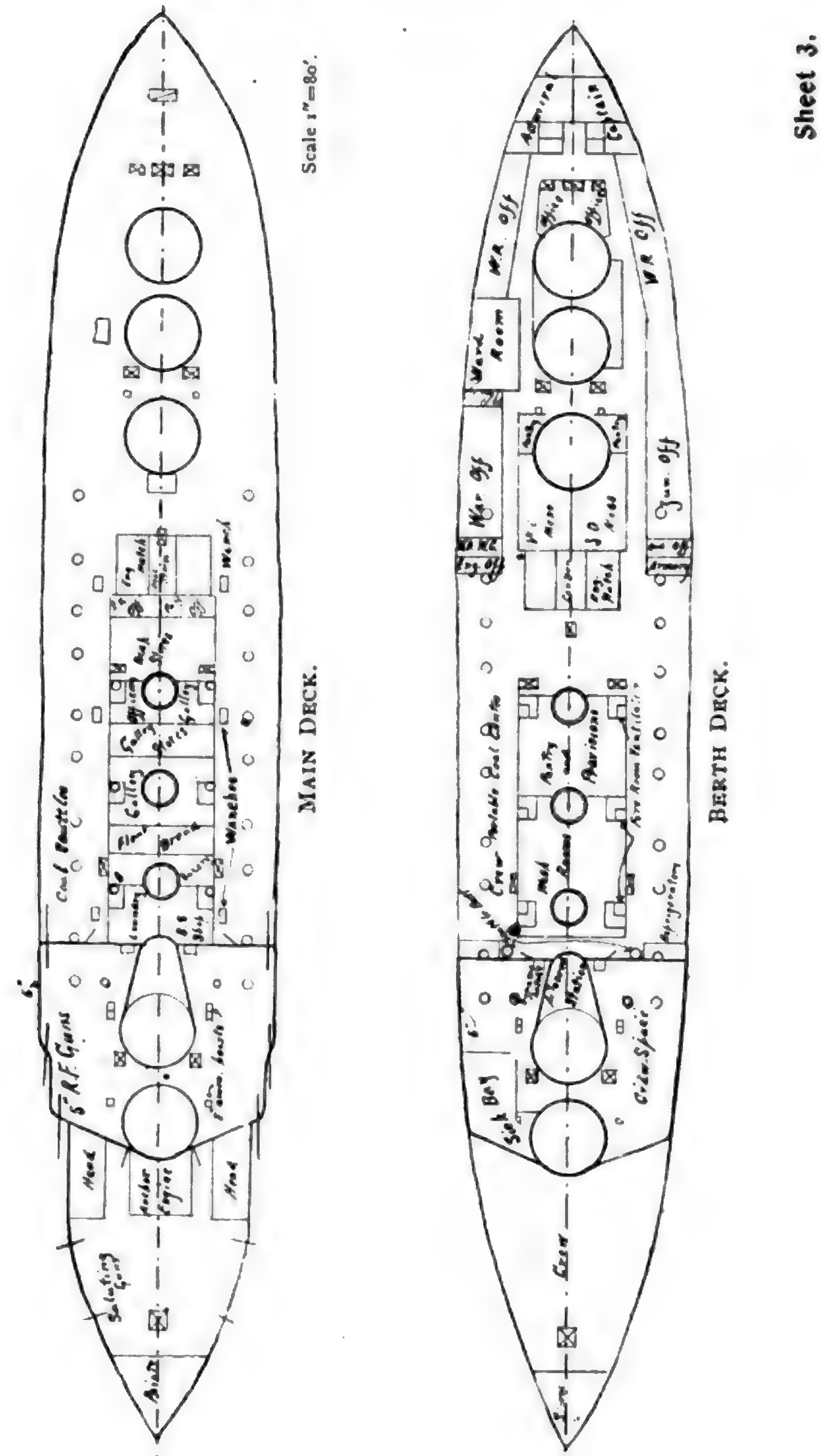
Sheet I.

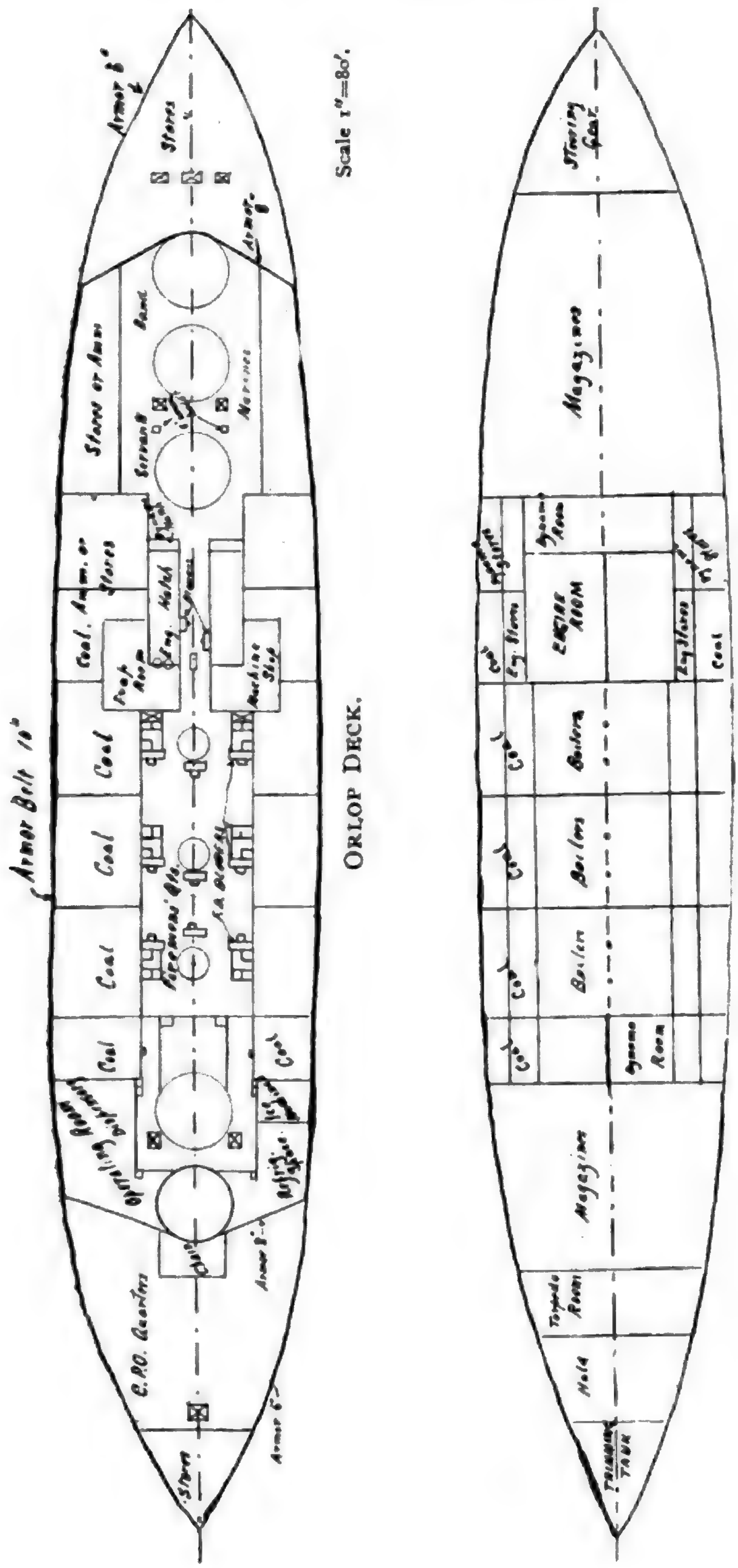
Sheet 2.



Scale 1" = 80'.

INBOARD PROFILE.


Sheet 3.
Scale 1"=80'.
Main Deck.
Berth Deck.
Hood
Anchor Engine
Hood
W.R. Off
W.R. Off
Ward Room
Sick Bay
Crew

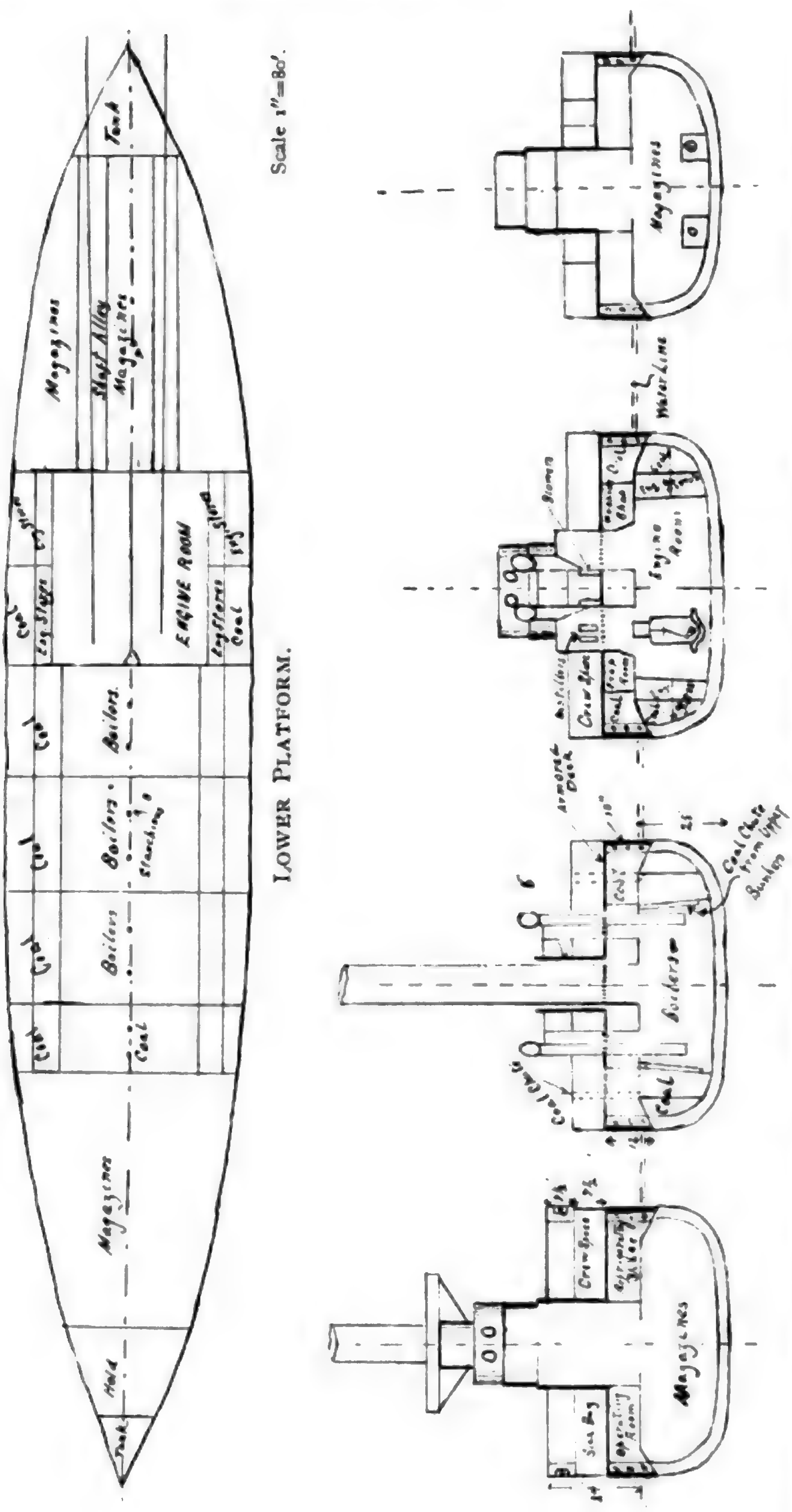


Scale 1" = 80'.

ORLOP DECK.

UPPER PLATFORM.

Sheet 4.



SECTION AT FORWARD TURRET, LOOKING AFT.

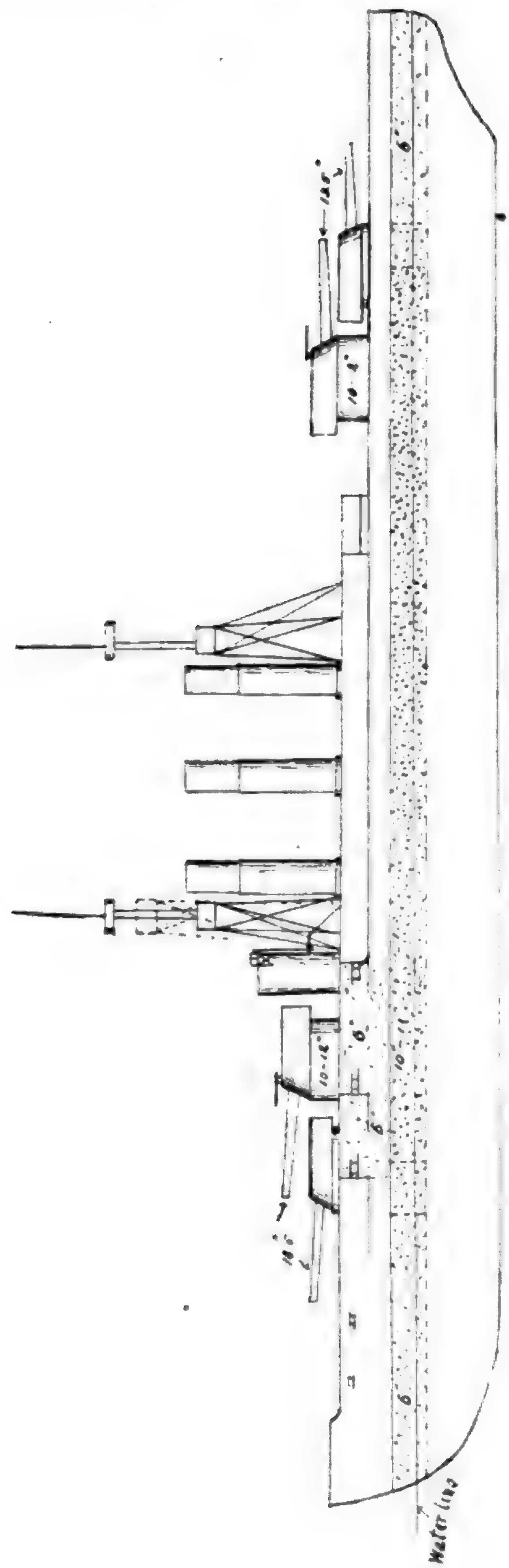
SECTION AT FORWARD SMOKE STACK, LOOKING AFT.

SECTION AT FORWARD PART OF ENGINE ROOM, LOOKING AFT.

SECTION AT 4TH TURRET, LOOKING AFT.

Sheet 5.

Sheet 6.



B. S. With Guns Larger Than 12-Inch.

NOTES.

LIQUID FUEL FOR INTERNAL COMBUSTION ENGINES.

By R. W. A. Brewer, A. M. Inst. C. E.

Since the gas engine was a commercial machine, the advantages of the use of a liquid fuel for driving this type of engine became apparent, and at the present time these advantages have become so enormous that there is quite a likelihood of the liquid-fuel internal-combustion engine superseding a large proportion of the steam units now in use. Manufacturers are designing and building these engines in constantly increasing sizes, and it is, perhaps, still a debatable point whether large marine engines of this type can be successfully used or not.

Liquid fuels must not be considered solely as the products of petroleum, because the control of that market is in the hands of a very few large companies. It is necessary to have one or more alternative fuels, in order that purchases of fuel can be made in an open market. It is, therefore, essential that engines designed for liquid fuel should be capable of being run on these alternative fuels without material alterations in their gear. The manufacture of a national fuel, as distinct from an import from foreign countries, should receive every encouragement, as such a fuel could not be a monopoly, and it is reasonable to expect that its price would be maintained at a steady and low figure.

We have recently seen how a great and concerted effort to encourage the use of alternative fuels has had the effect of reducing the price of a petroleum product, which points to the fact that at the present time the prices demanded by the large oil companies are false ones.

ATTEMPTS TO UTILIZE THE HEAVIER OIL.

In order to successfully utilize a liquid in the form of oil in the cylinder of an internal-combustion engine, two distinct methods have been tried to cope with the difficulties present. The fuel can be introduced:

1. As oil, *without* chemical change, either in an atomized or partly vaporized and partly atomized form.

2. *With* chemical change, such that the oil before entering the cylinder has been wholly or partially decomposed into the lighter hydro-carbons.

In the first group may be classed the first commercially successful engine, the Priestman, although in its effect it borders on case two. Distinct from this type is the Diesel engine, which works by compressing the air alone up to about 700 pounds per square inch. Into this highly compressed air at the end of the inward stroke of the piston is injected the correct proportion of liquid fuel, by means of air at a higher pressure operating a jet. As this fuel enters the cylinder it burns spontaneously, without a sudden rise of temperature, throughout a greater part of the working stroke.

Finally, there is the Roots type of engine, which has the low or ordinary compression of about 70 pounds per square inch, in which each charge of oil is accurately measured, and injected into the engine cylinder during the suction stroke, and in which chiefly atomization is relied upon to produce proper carburation of the air in the cylinder.

Under type 2 come all engines having externally-heated vaporizers, in which the liquid fuel is first converted, by partial decomposition, into a gaseous or semi-gaseous state before its introduction into the engine cylinder. A chemical change takes place in this vaporizer, and there is always the likelihood of deposits of carbon or heavy residuals forming here. Any possible variation in temperature between the vaporizer and the induction pipe will cause the vapor to condense in the pipe or round the inlet valve before it reaches the engine.

THE SOURCES OF SUPPLY AND THE QUESTION OF PRICE.

As far as we in this country are concerned at the present time, the United States of America can be almost ignored as a source of supply for the petroleum fuels. Originally, practically all the lighter distillates of petroleum imported into this country were obtained from the Pennsylvanian fields, as there was only a small percentage of petrol in the Russian oil, our other source of petroleum at that time.

Now the home consumption of American spirit has reached such proportions, together with the depletion of the wells in that country, that the amount available for export is very small. Whereas in 1905 we imported 10½ million gallons of petroleum spirit from America out of a total of 18½ million gallons, this importation had fallen to 2½ million gallons for the first six months of 1907, a decrease to less than 20 per cent. of the total amount imported.

The great increase in the demand for petroleum spirit in this country is shown by the following figures supplied by Mr. Alexander Duckham:

	Imperial gallons.
Year 1904	11,972,000
1905	18,658,000
1906	26,792,000

and the percentages of imports from the different sources have been as follows:

Country.	1904 Per cent.	1905 Per cent.	1906 Per cent.
United States	50	56	29.8
East Indian group	37	42	61.4
Roumania	8.2	0	8.6
Other countries	4.8	2	0.2
	100	100	100

These figures show the change in the sources of supply during the last few years, which change is still more marked for 1907.

Russian oil contains practically none of the lighter fractions which have been used in the past for motor spirit. Also

the labor disturbances in Russia account for its absence from the above list.

Roumania, on the other hand, does a large export trade in spirit, the bulk of which goes to France and Germany.

Roumanian Spirit obtained, in gallons.

	Gallons.
1903	14,500,000
1904	18,600,000
1905	23,500,000

The bulk of the spirit now coming into this country is from the fields of Sumatra, Borneo and the East Indies, and it is only within the last few years that the companies operating these fields have exported their light products to Europe. The oil from these fields contains a large percentage, up to 20 per cent. of a spirit distilling between 60 degrees C. and 150 degrees C., and referred to by the author as Borneo spirit, and also a considerable quantity of the more familiar Shell spirit, having a specific gravity of 0.715 to 0.720. The amount of spirit available from these fields depends upon the market for kerosene and other residuals. Sir Marcus Samuel in a recent speech stated that although they could produce an enormous quantity of spirit, "the price would depend upon whether they could find remunerative markets for the other products left when the petrol was removed from the crude."

As these products constitute something like 90 per cent. of the total, there is very little assurance that the petrol market will continue in a stable condition for any length of time. The price obtained for the residuals is primarily governed by the price of coal; for instance, Russia at the present time utilizes the bulk of its production locally as fuel oil. It would not pay to distil this oil for the sake of a small percentage of petrol. The removal of the specific-gravity standard might make the necessary difference, as far as Russia is concerned, whether it would pay to distil or not.

Considering the East Indian oil, in addition to the demand for fuel oil, which is very small, the chief marketable residual is kerosene. The companies, however, find this market decreasing year by year.

FLUCTUATIONS IN THE PRICE OF PETROLEUM.

As compared with other fuels petroleum products show unaccountable fluctations. This is undoubtedly due to the fact that the control of supplies is in very few hands. It is, therefore, an easy matter to create artificial prices, which must be paid by the consumer. Users of liquid fuels of the heavier types know how difficult it becomes to enter into any sort of contract for supplies, and that when sums of money have been expended in fixing apparatus for burning heavy liquid fuels, the price of such a fuel is raised until no economy results in return for the change.

As regards the lighter fractions, some idea of the fluctuation in price can be gathered from the following list of prices to agents in London, for spirit delivered in cans and cases:

	Per gallon. *Pence.*
November, 1904	7
November 20, 1905	8
January 19, 1906	9
February 21, 1906	9½
May 3, 1906	10
August 2, 1906	12
December 24, 1906	13
July 26, 1907	12

The final reduction of one penny occurred simultaneously with the issue of the report of the Fuels Committee of the Motor Union.

This serious rise in price has proved almost disastrous to users of commercial and public vehicles, particularly motor omnibuses, in connection with which the margin of profit is so small. The larger companies have contracted for supplies at a low figure, but the early contracts are now expiring. All the later contracts have been made at higher figures, and whilst the earnings remain the same, the profits must decrease.

This all points to the necessity of healthy competition in the fuel market, and several alternative fuels have been suggested for use in a high-speed internal-combustion engine.

When we look for a substitute for petrol, a home-produced fuel, which can be utilized without in any way altering the existing arrangements of the engine or carburetter, undoubtedly holds out great hopes. Such a fuel, known as benzol, is a distillate of coal tar, or can be extracted from coal gas. It is a light hydro-carbon, C_6H_6, and is a clear liquid similar in appearance to petrol, but having a slight smell of sulphur, due to the presence of about 150 grains of sulphur compounds per gallon. The specific gravity of pure benzol is 0.885; boiling point 80 degrees C. or 176 degrees F.

Total evaporation point of crude benzol is 145 degrees C. or 293 degrees F. and 1 gallon contains 163,680 British thermal units of heat, as against 157,142 B. T. U. for petrol, and has an explosive range from 2.7 to 6.3 per cent.

The largest source of supply is from coke ovens or gas works.

In the modern systems of coke manufacture for iron smelting the by-products obtained in the distillation of coal are collected instead of being allowed to go to waste, as in the old style of beehive oven. The benzol obtained in the gases from distillation is readily absorbed by means of suitable oils, from which it is afterwards extracted by distillation.

Commercial "90 per cent. benzol" is a spirit of which 90 per cent. evaporates in a retort at a temperature of 120 degrees C., and the production of which amounts to about 5,000,000 gallons per annum in this country. This supply could be largely increased by the installation of suitable recovery plant, should the demand warrant the expenditure. The supply could thus be doubled within a very short time. The present price of this fuel when refined is about 9d. to 10d. per gallon at the makers' works, the process of refining and washing costing about 1d. to 2d. a gallon. The process of washing by means of sulphuric acid and soda partially eliminates the sulphur compounds, but unwashed benzol might be made suitable for motor-car work by distilling out the lighter portions, and with them the bulk of the impurities.

EXPERIMENTS WITH 90 PER CENT. BENZOL.

With regard to the use of 90 per cent. benzol as a motor fuel, the author has made a number of experiments, the results of some of which are given below, and can be compared with those for petrol of various densities.

	Miles per hour.	Distance.	$\frac{EV^2}{C \times 100}$	V
	Long Test.			
Benzol, sp. gr. 0.875	27.2	116 miles	14.8	1
	Short Tests.			
Benzol, sp. gr. 0.875	24	14 miles	12.25	in traffic.
Benzol, sp. gr. 0.875	22	15 miles	12.4	in traffic.

The distances traveled per gallon compare very favorably with the best results obtained with petrol, viz:

0.715 specific gravity, 18 miles per gallon.
0.760 specific gravity, 21.5 miles per gallon.

The engine pulled well, and the speed of the car was kept about the same as when using petrol.

The author finds that on some occasions it is advisable to use rather a larger jet with benzol than with petrol, but care must be taken to admit sufficient air, or sooting takes place inside the cylinder. The smell of the liquid in the unburnt state is slightly more noticeable in the case of benzol, but the exhaust gases have little smell and no tendency to smoke.

In spite of what has been said against alcohol as a motor fuel, it is the author's opinion that alcohol has great possibilities in this direction. A clear statement is given in the Report dated July, 1907, of the Fuels Committee of the Motor Union as to the requirements and behavior of this fuel and to the high compression necessary to obtain the best results.

ALCOHOL AS A FUEL.

The author has obtained samples of commercial methylated alcohol having a specific gravity of 0.833, and with them conducted a number of tests, using other ingredients in varying proportions. He has succeeded in running his motor car sat-

isfactorily upon these mixtures and also with alcohol mixed with only 25 per cent. of another fuel.

The fact is here stated in order to refute many biased opinions which have been expressed of late, as to the impracticability of alcohol as a fuel for this purpose. Sir Marcus Samuel, in the speech previously referred to, remarked with reference to alcohol: "Although alcohol might prove an excellent bogey with which to attempt to frighten the producers of petrol, they did not entertain the smallest misgiving that this spirit could ever become a competitor to their petrol, for the simple reason that it did not contain those qualities essential for the running of motor vehicles."

Considering now these essential qualities, the properties of alcohol may be briefly summarized as follows: Ethyl alcohol C_2H_6O, a volatile colorless liquid with a specific gravity of 0.806 at 0 degree C. Calorific value about 12,600 B. T. U. per pound. Boiling point 78 degrees C. Explosive range 4 to 13.6 per cent. with air.

Methylated spirit, consisting of 90 per cent. ethyl alcohol and 10 per cent. methyl alcohol (CH_4O), has a calorific value of about 11,000 B. T. U. per pound.

The following is an approximate comparison:

	Petrol 0.722	Methylated spirit
Calorific value in B.T.U. per lb................	20,000 (gross)	11,000 (gross)
Net calorific value per lb., *i. e.*, heat converted into work..................................	4,248 B.T.U.	3,322 B.T.U.
Thermal efficiency =................................	21 per cent.	30 per cent.
Heat converted into work = Calorific value.		

In practice, a petrol motor rarely exceeds a thermal efficiency of 18 per cent., whilst with an alcohol motor the highest efficiency is readily obtained, and, considering that a gallon of alcohol weighs about 12 per cent. more than that of petrol, the net value per unit volume is about the same. A great advantage of alcohol is its uniformity of composition, the whole of the spirit distilling over at a temperature of about 78 degrees C.—"Page's Weekly."

ON THE INDICATED POWER AND MECHANICAL EFFICIENCY OF THE GAS ENGINE.

Paper read before the Institution of Mechanical Engineers, October 18, 1907, by Professor Bertram Hopkinson, Member of Cambridge University.

In the report of the Committee of the Institution of Civil Engineers on "The Efficiency of Internal-Combustion Engines,"* the following remarks occur (page 247):

"It would be desirable but for one circumstance to calculate the relative efficiency only from the indicator horsepower. But it appears that in the case of gas engines, and especially gas engines governed by hit-or-miss governors, the indicator diagrams do not give as accurate results as is generally supposed. The diagrams vary much more than those of a steam engine with a steady load, and the mean indicator horsepower, from the diagrams taken in a trial, may, it appears, differ a good deal from the real mean power."

This statement is fully borne out by the tests of the Committee, which show that the mechanical efficiency taken as the ratio of brake to indicated power varied from 80 per cent. to 94 per cent. in the three engines tested. These engines were of similar type, but of different sizes, and whereas the smallest, of 5 horsepower, showed a mechanical efficiency of 90 per cent., the intermediate engine, of 20 horsepower, showed a lower efficiency, of 80 per cent. The Committee remarked that these values were obviously incorrect, and the values adopted by them for the mechanical efficiency were obtained by running the engine light and making an estimate of the indicated horsepower under these conditions. Assuming that the mechanical loss is constant at all loads, the indicated power at full load can be determined by adding the power absorbed at no load to the brake power. The mechanical efficiencies of the three engines found in this way were respectively:

Engine	L	R	X
Mechanical efficiency	0.86	0.866	0.888

* Proceedings of the Institution of Civil Engineers (1905–6), Vol. lxiii.

These results are just what would be expected; the mechanical efficiency showing a slight improvement with the size of the engine.

The opinion of the Committee quoted above is obviously important and may be expected to have a widespread effect in gas-engine testing. It throws doubt upon many of the efficiency tests on gas engines which have hitherto been made and published. Moreover, the method which the Committee themselves adopted for getting the indicated power from the brake power seems to require further investigation before it can be accepted as accurate. It may no doubt be assumed on the evidence of steam-engine tests that, under given conditions of lubrication, the friction is practically independent of the pressure in the engine. But whereas in the steam engine the whole of the mechanical losses are to be ascribed to friction, that is not the case in the gas engine in which a considerable amount of power is wasted in pumping, and is usually included in the mechanical losses. Moreover, with a given supply of oil, lubrication conditions in the steam engine are practically constant, but in the gas engine that is by no means the case. Great changes can take place in the temperatures of the cylinder walls in a comparatively short time, and this will affect the viscosity of the oil, and therefore the work spent in friction. The author, therefore, determined to undertake an investigation with the object of finding whether the indicator power of the gas engine does, in fact, vary so much, and is so difficult of determination, as the report of the Committee referred to suggests. If it were found that the indicated power could be accurately determined directly, it was further desired to test, by direct comparison of brake and indicated power, the validity of the Committee's method of getting the mechanical efficiency. Briefly, the conclusions reached are:

1. If precautions are taken to keep the pressure of the gas supply constant, the diagrams given by the engine are remarkably regular, and, whether the engine be missing ignitions or not, it is possible, by the use of a sufficiently accurate indica-

tor, to obtain the indicated power from diagrams within 1 or 2 per cent. It seems probable that the difficulty experienced by the Committee was due either to the essential defects, for this purpose, of the ordinary form of indicator, or to casual variations in the gas supply per suction, due perhaps to variation in the gas pressure at the engine.

2. The difference between indicated horsepower and brake horsepower is rather less than the horsepower at no load under the same conditions of lubrication, mainly because of the difference in the power absorbed in pumping. In the particular engine tested by the author, the error from this cause in obtaining the indicated power would amount to about 5 per cent. The friction is substantially constant from no load to full load, provided that the temperature of the cylinder walls is kept the same, but the influence of temperature is very great.

The engine used in the tests was kindly placed at the author's disposal by Messrs. Crossley Brothers. It is intended to give a maximum output of 40 horsepower on the brake, and the following are the particulars of it:

Cylinder, 11½ inches in diameter by 21-inch stroke.

Speed, 180 revolutions per minute.

Compression space, 407 cubic inches.

Compression ratio, 6.37.

Compression pressure, 175 pounds per square in, absolute.

When exploding every time, the indicated horsepower at 180 revolutions per minute is 0.495 times the mean effective pressure.

The engine works on the ordinary Otto cycle, governed by hit-and-miss. The ignition is by magneto. The engine was loaded by belting it to a dynamo (lent by Messrs. Mather & Platt), which also served to motor it round when required. The fuel used was Cambridge coal-gas. When an accurate measurement of brake power was desired all round rope-brakes were used, one on each flywheel; and as the measurements were such that the brake tests only lasted a few minutes, it was not necessary to use any water cooling. The engine was fitted with an exhaust gas calorimeter of the spray type.

For measuring the gas supply a standard holder by Messrs. Parkinson & Cowan, having a capacity of 10 cubic feet, was placed between the main gas supply and the engine, and as close as possible to the latter. In the ordinary running of the engine the holder stood at a constant level, the flow of gas into it just balancing the flow out, and under these conditions it served as a gas bag, coming down by about one-tenth of a cubic foot at each suction of the engine. In a measurement of gas consumption the supply to the holder was cut off, so that the engine took gas only from the holder, and the quantity taken in a definite number of suctions (usually about 50) was noted. The indicator diagrams were photographed at the same time as this measurement was made. After the completion of the measurement the inlet pipe to the holder was opened, and the counterweights adjusted, so that the holder slowly rose to nearly its highest position, when the measurement could, if necessary, be repeated. It was possible in this way to read off the gas consumption correct to one part in 500, and, allowing for possible inaccuracies in the gas-holder divisions, small changes in temperature and pressure, etc., it may be taken as certain that the gas consumption given is within one-half per cent. of the truth. This method of gas measurement is, of course, especially adapted for cases like the present, in which the actual gas used in a particular cycle or series of cycles is desired; but it may be noted that it is almost equally suitable for the measurement of gas consumption for a long period. It was found that it made no perceptible difference to the power given by the engine whether the inlet pipe to the holder was open or closed, and it may be assumed, therefore, that the gas consumption remains the same under these two conditions. The rate of consumption determined by the holder may therefore be assumed to hold during the intervals when the holder is filling, or is standing at a constant level. This method of measurement, which is much superior in accuracy to any meter, and is very convenient, might easily be applied to much larger engines, since all that is required is a holder of capacity sufficient to run the engine for about one minute.

The work of making the tests and reducing the results was done almost wholly by two students of the engineering laboratory—Messrs. A. R. Welsh, of Trinity College, and A. L. Bird, of Peterhouse. To these gentlemen the author must express his thanks. Without their assistance it would have been impossible for him, with the time at his disposal, to have carried through the series of tests which is here described.

The first requirement for the investigation proposed was an accurate indicator. In order to get at all satisfactory results, it was necessary to construct an instrument which could be relied upon absolutely to give the indicated power within 2 per cent. Further, it was necessary that the instrument should be capable of working for long periods without breaking down, so that large numbers of diagrams could be taken under given conditions. The author's experience of indicating gas engines has convinced him that it is quite impossible to fulfil the first of these conditions, to say nothing of the second, with any form of pencil indicator. It is unnecessary to discuss here the various sources of error in the pencil indicator, but it may be noted that two of them—namely, the inertia of the piston and looseness in the joints—are of especial importance in the gas engine. In the engine on which the experiments here described were made the pressure rises on explosion from 170 pounds to 500 pounds, or 600 pounds per square inch in less than .01 second. Now, the natural period of oscillation of a Richards indicator of the kind made by Cassartelli, of Manchester, for gas-engine work, when working with a three-hundred spring, is of the same order—that is, about .01 second. In consequence of this, as is well known, violent oscillations may be set up by the explosion, and continue along the expansion line of the indicator. The magnitude of these oscillations depends upon the relation between the time taken by the pressure to rise to its full value and the period of oscillation of the indicator. Thus with certain gas charges there may be practically no oscillation, while with a slightly different mixture the oscillations may become so great as to make accurate measurement of the diagram impossible. The effect of indicator

inertia on gas-engine diagrams is well known; but the other defect referred to—namely, backlash in the mechanism—has not, I think, been fully appreciated, though it is fairly obvious. The maximum pressure in a gas engine in which the compression ratio is 6 to 500 pounds to 600 pounds per square inch, and it is necessary therefore to use a very stiff spring. Stiffness is also required to reduce the natural period of the instrument, and so to bring within reasonable limits the oscillations due to inertia. In practice the author has found that in the Crosby indicator a spring giving a deflection of 1 inch with a pressure of 300 pounds per square inch is barely stiff enough. Now, the mean pressure is about 100 pounds per square inch, giving a mean height with this spring of 0.3 inch; slackness in the joints amounting to a total movement of the pencil of .01 inch will therefore cause an error in the diagram area of 3 per cent.

The author has examined a considerable number of pencil indicators for backlash, and has not yet succeeded in finding one, even when perfectly new, in which it amounts to less than 1.5/100 inch, and in very few is it less than .02 inch, giving an error of 6 per cent. in the diagram area. It is by no means surprising that this should be so when one considers that in the Crosby indicator motion there are four pin-joints between the piston and the pencil, and that the motion is magnified six fold. Thus a movement of .01 inch at the pencil corresponds to only 1.24/100 inch at each joint. Another error of the same kind is that due to the deformation of the lever carrying the pencil set up by friction of the pencil on the paper. The combined effect of this and of backlash is to increase the mean height of the diagram by an amount which, from the nature of the case, is quite uncertain, but which may easily reach 1/30 inch even with a new indicator in perfect adjustment. This error is in most instruments counter-balanced to some extent, and in many overbalanced, by that due to motion of the pencil at right angles to the piston bore.

The pencil motion should, of course, be accurately parallel to the piston motion, but in all indicators looseness in the joints

prevents this motion from being perfectly definite. The pencil can move anywhere between two parallel lines, and the friction between pencil and drum is quite sufficient to make it take either of these. In the diagram, the expansion line and compression line are both shifted inwards, and the area and mean pressure reduced. This defect is sometimes rather serious in the Crosby indicator, which in other respects is as good as a pencil indicator can be for gas-engine testing. The author has never found it amount to less than .02 inch, and the mean pressure taken with this instrument is, in consequence, often too small. Using a three-hundred spring the mean pressure taken from a diagram 2½ inches long from a gas engine compressing to 170 pounds per square inch absolute will be 3½ per cent. too small if the horizontal backlash amounts to .02 inch. Stretching of the chord caused by drum friction of the kind discussed by Professor Osborne Reynolds acts in the same way. It would appear that on account of these disturbances, in themselves so minute, gas-engine diagrams taken with a pencil indicator cannot be relied upon as accurate to within 5 per cent., and the error must often be more like 10 per cent. When the indicator is subjected for any considerable time to the wear and tear involved in recording the explosions of a gas engine with high compression and using heavy charges, its joints rapidly become so slack as to destroy its value for any but the roughest measurements. Indeed, it may almost be said that the life of a pencil indicator (as an instrument of precision) when used on such a gas engine is limited to a few hundred explosions.

To overcome both these defects of inertia and backlash, it is necessary to reduce very much the motion of the moving parts of the indicator, and to use optical means for magnifying that motion. The diaphragm manograph first proposed by Perry, and now in use to some extent as a commercial instrument in the form of the Hospitallier-Carpentier manograph, is unsuited for accurate quantitative work, for a number of reasons, the chief of which are that the displacement is not proportional to the pressure, so that the diagrams cannot be inte-

grated by a planimeter, and that it is inconvenient to calibrate. The author therefore determined to get a new design of indicator of the piston-and-spring type with optical magnifying mechanism. In the form finally adopted, after a considerable amount of experimenting, the spring consists of a straight piece of steel strip held as an encastred beam in a steel frame. A piston slides in a bore communicating with the engine, the axis of this bore being at right angles to the spring and passing through its center. The pressure on the piston deflects the spring, and so tilts a small mirror about an axis at right angles to the bore, the pivots of this mirror being carried on a steel frame. To give the other motion to the mirror the whole apparatus (straight spring and mirror with its pivots) is positively connected to an eccentric on the crank axle, by which it is rocked about the axis of the bore, thus giving the piston motion of the diagram without the possibility of any lost motion. This instrument is practically indestructible, and it has been left open to the engine for considerable periods without giving it any attention. The vertical deflection is accurately proportional to the pressure, so that the diagrams can be integrated with a planimeter. Finally, the period of oscillation is only about 1/700 of a second with such strengths of spring as were used in the mechanical efficiency tests. The indicator is very easily calibrated by dead weights. The diagrams used in these measurements were photographed; but for many purposes it has been found sufficient to observe them direct by means of a telescopic arrangement by which they are projected as a bright line of light on to a transparent screen with vertical and horizontal scales. It is easy to plot the diagram on to a piece of squared paper, and its area can thus be obtained within 5 per cent. without the trouble of photography.

Fig. 1 is a facsimile of a normal diagram taken with this instrument; it represents about a dozen consecutive explosions. In order to determine the accuracy with which the indicated power can be determined, three diagrams similar to this were taken, each comprising twenty consecutive explosions, and these were integrated by separate observers directly from the

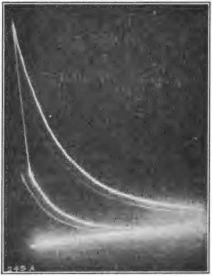


Fig. 1.—Facsimile of Normal Diagram Representing About a Dozen Consecutive Explosions, Taken with Indicator, Figs. 4, 5.

negatives, each diagram being dealt with by two observers, so as to get six independent integrations. In the result the mean of all the measurements was found to be 0.954, the maximum being 0.963, and the minimum 0.940.

This test was considered to have established the accuracy of the instrument, subject to the calibration being correct. It also proves that the diagram, when the engine is exploding continuously, is quite remarkably regular. It is certain that in a continuous series of, say, a hundred explosions the diagram area does not vary more than 1 per cent. on either side of the mean value. When the governor cuts out charges of gas, however, a slight enlargement of the diagram is sometimes perceptible in the cycle following a miss. Occasionally this enlargement amounts to as much as 4 per cent., while at other times it disappears completely. On theoretical grounds it is to be expected that the gas taken after a miss will be, if any-

thing, slightly less than after an explosion. On the other hand, the efficiency is slightly higher. But whatever the cause of the slight difference in area, it is clear that it can have no practical effect in an ordinary full-load trial, since it only happens once in five or six cycles. It may therefore be taken as definitely established that, given a sufficiently accurate indicator and constant conditions, the indicated horsepower of a gas engine may be determined from diagrams with an accuracy which is probably superior to that attainable in the steam engine.

The indicated horsepower of the engine is dependent, of course, upon the gas supply. In the tests described above the amount of gas taken per cycle was, no doubt, very constant, but it is probable that under certain circumstances there may be casual variations of gas supply which give rise to varying diagrams. The gas taken per suction with a hit-and-miss governor is determined by the temperature of the cylinder walls and piston and by the opening of the gas cock. So long as these variables and the pressure in the mains are kept constant there is no reason why the gas consumption should vary. In the trials described in this paper a gas holder of considerable capacity was placed close to the engine, and the pressure in the holder was, no doubt, very nearly constant; but that, of course, may not be so in all practical tests. The mean pressure in the cylinder during the suctioin stroke is about 2 pounds per square inch below atmosphere, equivalent to about 55 inches of water. A variation of 2 inches or 3 inches of water in the pressure outside the engine, therefore, gives a substantial change in the gas supply. Such a variation would naturally occur after a missed ignition, if the gas bag were not of very ample capacity and placed close to the engine, and this may to some extent account for the very considerably enlarged diagrams which in some engines have been observed to follow a miss.

Changes of cylinder temperature considerably modify the gas consumption per cycle with the same opening of the gas cock, but these changes are, of course, comparatively slow, and

do not affect the accuracy of an estimate of indicated power where the conditions are fairly constant. As an indication of their amount the following test may be cited. The engine was first run light with a large flow of jacket water; it was then fully loaded and the jacket water throttled until the temperature at exit rose to 185 degrees Fahr. (85 degrees Cent.). The load was then suddenly thrown off, and the engine was allowed to run light for a short time with the hot jacket. A large quantity of water was then passed through the jacket, so that the temperature of the cylinder rapidly fell to 61 degrees Fahr. (16 degrees Cent.). The gas taken per suction was measured at intervals, with the results shown in Table I.

TABLE I.

Jacket temperature, outflow.	Load.	Gas, cubic feet per suction.
58° to 65° F. (14° to 18° C.)	Nil	0.1217
* 72° F. (22° C.)	Full	0.1124
114° F. (45° C.)	Full	0.1103
185° F. (85° C.)	Full	0.1072
*196° F. (91° C.)	Nil	0.1117
185° F. (85° C.)	Nil	0.1141
179° F. (81° C.)	Nil	0.1159
61° F. (16° C.)	Nil	0.1205

It will be noted that the gas consumption varies between limits differing by 12 per cent., and the indicated power would change in almost the same ratio. The change in the gas consumption at and following the points marked * is mainly due to the change of temperature of the piston, which very rapidly follows any change of load.

It will be desirable to give a statement of the meanings which will be attached in this paper to the terms "indicated power," "mechanical loss," &c.

Indicated Power is the area of the positive loop of the indicator diagram multiplied by the number of explosions per minute, and by the appropriate constant for reducing to horse-power.

Mechanical Loss is the difference between indicated power and the brake power delivered at the circumference of the fly-

wheels. It includes the negative loop of the working diagrams, and also the negative work done when the engine takes no gas.

Mean Effective Pressure is the mean pressure calculated from the positive loop of the indicator diagram. It is sometimes convenient to speak of the "mean pressure effective on the brake," and this is equal to the mean effective pressure multiplied by the mechanical efficiency.

Mechanical Efficiency is, as usual, the ratio of brake to indicated power (the latter being defined as above).

Thermal Efficiency is the ratio of indicated power to the lower calorific value of the gas used, the two quantities being, of course, reduced to the same units.

A large number of tests were made with the object of determining the mechanical losses by finding the difference between indicated power and brake power, and of comparing the result with that obtained from running the engine light under the same conditions. It will be well to describe one of these tests in detail, and to summarize the results of the others. The engine was run with a fairly full load, missing about one explosion in five cycles. The load was applied by means of rope brakes, and, as the test only lasted a short time, it was unnecessary to employ any water cooling. While careful observations were taken of the brake load (the difference between a dead-weight and a spring balance) three photographs of indicator diagrams were taken, each photograph covering about a dozen explosions. At the same time the misses occurring in about a couple of hundred cycles were counted, so that the ratio of missed ignitions to cycles was accurately known. These observations gave all the data for the mechanical efficiency, no observation of speed being necessary; the speed was, however, kept approximately constant by the governor at 180 revolutions per minute, and in what follows brake power and indicated power are both calculated on the assumption that that was in fact the speed of the engine. The following are the results of measuring the three photographs, together with the observations taken at the same time as the photographs:

TABLE II.

Jacket, exit temperature.	Explosions, cycles.	M.E.P. from diagram.	Gas per suction. Cu. ft.	I.H.P.	B.H.P.
150 deg. F. (65 deg. C.)......	0.804	100.3	0.1196	39.7	34.0
......	0.82	99.4	0.1182	40.2	34.6
160 deg. F. (71 deg. C.)..	0.825	99.0	0.1164	40.2	34.9

The gas charge was measured, as described above, by means of a standard holder, and is correct to within 1 part in 200. It will be seen that the mean pressures from the three diagrams show very good agreement, being all within 1 per cent. of the mean value after allowing for the small change in gas charge. The mean of the three observations of brake horsepower is 34.5. The mean indicated power is 40, giving a mechanical efficiency of 86.2 per cent. The difference between brake and indicated horsepower ranges from 5.7 to 5.3 horsepower, the mean being 5.5 horsepower. In the course of the test the jacket temperature rose slightly, and, as will shortly appear, this is sufficient to account for the small diminution in mechanical losses observed in the course of the test.

Immediately after the completion of the above full-load tests the brakes were taken off and the engine run without load, the jacket water being throttled so as to prevent the engine from cooling down rapidly. Photographs were at once taken of the indicator diagram, the gas consumption was measured, and the ratio of explosions to total cycles was ascertained to be 0.141. The mean pressure was found to be 105.5 pounds per square inch, the gas consumption 0.1252 cubic feet, giving 7.35 indicated horsepower, or about 1.85 horsepower more than the difference between the indicated horsepower and the brake horsepower in the full-load tests. Had the engine in the latter case been firing every time instead of four times out of five, this difference would have been increased in the ratio $\frac{5}{4}$, becoming 2.3 horsepower.

This result—that is, that the power taken to turn the engine round at light load is rather over 2 horsepower more than the mechanical losses at full load, which was verified on many

occasions—is due almost wholly to the difference in power absorbed by the pumping strokes of the engine at light load and at full load. This difference appears in Fig. 2, which shows the suction loop in the two cases. The full line is the diagram of a cycle in which no gas is taken, the dotted line shows the negative part of a diagram of a cycle in which gas is taken. It will be seen that, as usual in these engines, the exhaust line after an explosion is considerably lower than when the engine is simply exhausting a charge of air. Moreover, when the engine takes gas, the pressure at the middle of the suction stroke is about a pound higher than when the engine is taking air only—no doubt because of the less restricted opening in the latter case. The mean pressure of the full-load suction loop is 2.9 pounds per square inch, corresponding to 1.4 horsepower at 180 revolutions; whereas in the other case the pressure is 5 pounds per square inch, giving 2.5 horsepower. In addition to this a certain amount of work is done in the compression and expansion of the charge of air which occurs when no gas is admitted, the compression line being rather higher than the expansion line. It is difficult to show the whole of this work area on a diagram, because if the spring of the indicator is sufficiently stiff to take the maximum compression pressure of 170 pounds per square inch, it is hardly sufficiently sensitive to record the small difference of pressure between the expansion and compression strokes. From a good many observations of diagrams with different strengths of spring, however, and also from calculations based on the loss of heat during compression, it would appear that the mean pressure of this part of the diagram is certainly between 1.5 pounds and 2.5 pounds per square inch. On this account, therefore, 1 horsepower must be added to the negative work done in each cycle in which no gas is taken, making approximately 3.5 horsepower at 180 revolutions per minute. This is 2.1 horsepower more than the power represented by the negative loop when the engine is firing every time, and is therefore just about sufficient to account for the difference between the full-load mechanical loss and the light-load indicated power.

An independent estimate of the power lost in pumping was made by belting the engine to the dynamo and motoring it round without allowing it to take gas. Two measurements were made, one immediately after the other; in one the engine was closed up as usual; in the other the exhaust-valve cover was removed, so that there was no pressure in the cylinder. Assuming that the belt losses and friction losses are the same in the two cases, the difference between the powers absorbed by the dynamo (after deducting dynamo losses) should be equal to the power absorbed in pumping. Two tests gave the following results, the jacket temperature in both cases being 180 degrees F. (82 degrees C.):

	Aug. 24.	Aug. 25.
Engine closed: horsepower...	7.72	7.1
Engine opened: horsepower..	4.14	3.77
Difference	3.58	3.33

The mean is 3.45 horsepower against 3.5 horsepower estimated from indicator diagrams.

In comparing the mechanical loss with the light-load indicated power, care was taken that the conditions of the engine as regards lubrication and cylinder temperature were as nearly as possible the same. It was found that these factors make a very great difference to the engine friction, and it is important to allow for this in basing any estimate of indicated power upon the power absorbed by the engine at light load. This point is strikingly illustrated by an experiment which was made immediately after one of the tests for mechanical efficiency. At the end of that test the jacket temperature was 179 degrees F. (81 degrees C.), the engine was absorbing about 7 horsepower, exploding once in seven cycles, and the ordinary normal lubrication was going on. The gas consumption was 0.1159 cubic foot per suction. With the engine running under these conditions, and without stopping it or altering the conditions in any other way, the jacket water, which had previously been shut off, was turned fully on, so that in a few minutes the jacket temperature had fallen to 61 degrees F. (16 degrees C.). The gas consumption was then found to have risen to 0.1205

cubic foot per suction, or by about 3 per cent., and the engine was taking gas once in 4.85 cycles. Thus the power absorbed had increased, in consequence of the reduced cylinder temperature, to 10, or by about 40 per cent. on its value with the hot cylinder. A considerable quantity of water was then injected into the cylinder through the small suction valve which

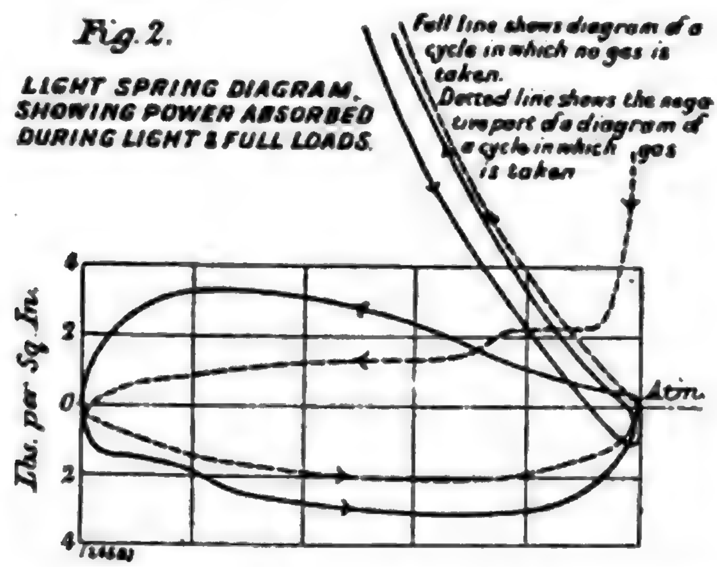


Fig. 2.
LIGHT SPRING DIAGRAM. SHOWING POWER ABSORBED DURING LIGHT & FULL LOADS.

is fitted for the purpose of preventing preignitions. The result of this was an immediate drop in the power absorbed to about 6 horsepower, or rather less than the engine was using with the hot jacket and with the normal lubrication. This very great variation in the power absorbed by the engine in friction must, of course, be within the experience of many people who have worked practically with gas engines, and it is referred to here mainly because it is so important a factor in the testing of these engines for mechanical efficiency. In the full-load test immediately preceding this experiment the brake power was 36.2, and if the indicated power had been calculated by adding to the brake power the horsepower absorbed at no load, the result might have been anywhere between 43.2 and 46.2 according as the light-load tests were done with a cold or with a hot jacket. The indicated horsepower was determined by measurement of the diagram to be in fact 41.2.

Confirmation of the great variation of power absorbed with the condition of the cylinder was obtained by motoring the engine round. The exhaust-valve cover was taken off the

engine, so that the cylinder was open to the air, and there was no loss from pumping. The power taken to drive the dynamo was measured electrically, and the dynamo losses were deducted, so that the results given below are the total frictional losses in the engine plus the loss in the belt (probably about 0.5 horsepower).

	Power Absorbed.
Engine hot (about 180 degrees F., 82 degrees C.): Normal lubrication...............	4 H.P.
Engine cold (70 degrees F., 21 degrees C.): Normal lubrication...............	6.5 H.P.
Engine cold (70 degrees F.): Excess of oil..	4.7 H.P.
Engine cold (70 degrees F.): Water injected.	2.7 H.P.

A separate determination of the power required to drive the engine round with the piston removed was made, and it was found to be 1.4 horsepower. This includes the main-bearing friction, valve-lifting, and belt losses. If this be deducted from the figures given above, the result is the piston friction, which, of course, is alone affected by the changes in cylinder temperature and lubrication. It will be seen that the piston friction varies according to conditions between 1.3 and 5.1 horsepower, the normal value with jacket at 180 degrees F. being about 2.5 horsepower.

In normal working at nearly full load (41 indicated horsepower), with the jacket at 180 degrees F., the mechanical losses in this engine may be allocated as follows:

TABLE III.

......	Horsepower.	Per cent. of I.H.P.
Suction	1.4	3.4
Piston friction	2.5	6.1
Other friction (valve lifting, &c.)	1.1	2.7
Total	5.0	12.2

The apportionment between piston friction and other friction is somewhat uncertain, as it may be to some extent affected by the existence of pressures in the cylinder, the estimate of

piston friction being based upon running the engine with the cylinder open to the air.

The effect of using water as a lubricant when the cylinder is cold is, of course, easy to understand, though the author hardly expected to find that it was so great in amount. It is not quite so marked, though still quite perceptible, when the engine is running fully loaded. In one test, in which the engine was fully loaded and the jacket water at a temperature of about 180 degrees F. (82 degrees C.) at exit, it was found that injection of water in considerable quantity diminished the number of explosions per minute by about 3 per cent. with the same brake load and speed. This difference is due entirely to the change of lubrication, the water having no effect whatever upon the indicator diagram.

TABLE IV.

Date.	Jacket temperature.	Loss. H.P.
August 16, 1906	150–160 degrees F. (65–71 degrees C.)	6.0
August 22, 1906	185 degrees F. (85 degrees C.)	5.0
August 22, 1906	185 degrees F. (85 degrees C.)	4.9
January 31, 1907	69 degrees F. (20 degrees C.)	7.1
January 31, 1907	150–160 degrees F. (65–71 degrees C.)	5.5
January 31, 1907	203 degrees F. (95 degrees C.)	4.5

The table above gives the mechanical loss in this engine observed under different conditions. The lubrication is in each case normal, and the loss is the difference between the observed brake power and the indicated power. The engine was nearly fully loaded in every case, the proportion of idle cycles varying from 0.17 to 0.20.

The results show the effect of jacket temperature. The slight reduction in loss as between the August and January experiments is to be expected, because the engine was run a good deal in the interval.

The following is a summary of the various efficiency figures relating to this engine:

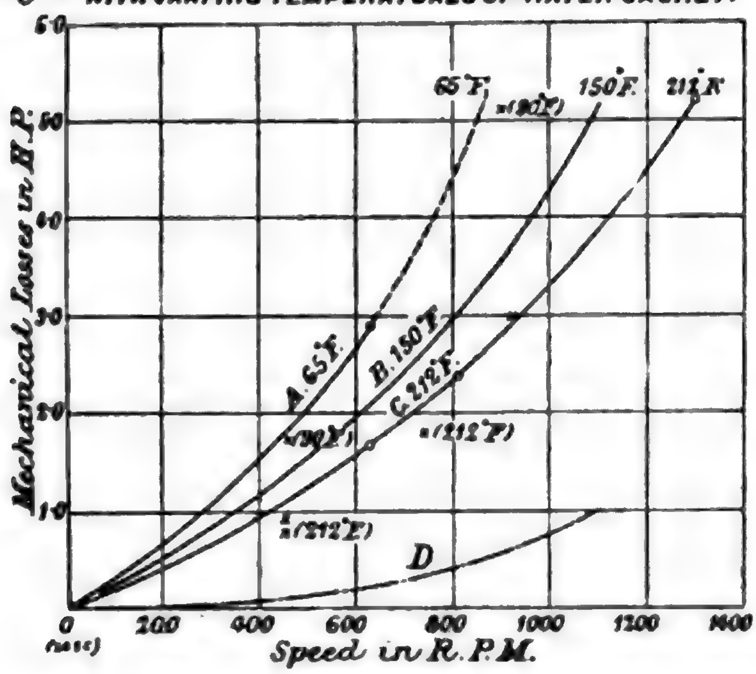
TABLE V.

Thermal efficiency........................	33½ per cent. to 37 per cent., according to strength of mixture.*
Mechanical efficiency for medium charge......................................	85 per cent. to 90 per cent., according to jacket temperature.
Air-cycle efficiency......................	52.2 per cent.
Efficiency relative to air cycle......	0.64 to 0.71.

It may be interesting in this connection to give the results of a series of tests for mechanical efficiency which were made upon a gas engine of a very different type—that is, a four-cylinder petrol motor running up to 1,200 revolutions per minute. The engine was kindly lent to the author by the manufacturers, the Daimler Company, Limited, and has cylinders 3.56 inches in diameter, with a stroke of 5.11 inches. The mechanical losses were determined by the method described by the author in a paper in "Engineering" (February 8, 1907). The method consists in running one cylinder only of the engine and of indicating that cylinder, there being no load on the engine. The indicated power of the single cylinder is then equal to the mechanical friction of the engine plus the negative work shown on the diagrams of all the four cylinders. When the engine is running fully loaded at the same speed, the loss by mechanical friction will be substantially unaltered, but the suction losses will not be quite the same, owing to the same causes that operate in the case of the large gas engine. The suction loops in the three idle cylinders are different from that in the firing cylinder, and there is, moreover, the negative work done in the compression and expansion. The pumping losses, however, in the Daimler engine bear a very much smaller proportion to the whole than in the large gas engine, owing to the relatively great size of the ports, so that no serious error is involved in neglecting the difference in these losses as between firing and not firing. Fig. 3 shows the relation between the power indicated by the single cylinder and the speed for three different temperatures. In curve A the outlet temperature

* The weaker mixtures give the higher efficiency. Full details of the tests establishing this fact will be given in a further communication.

Fig. 3. MECHANICAL EFFICIENCY OF DAIMLER ENGINE WITH VARYING TEMPERATURES OF WATER JACKET.



of the jacket water was 65 degrees F. (18 degrees C.) in curve B about 150 degrees F. (65 degrees C.), and in curve C the water was just boiling. The dotted curve D shows the power absorbed in pumping, estimated from light-spring indicator diagrams; so that the difference between this curve and any one of the others gives an approximation to the loss by mechanical friction. These curves show that the frictional losses at a temperature of 65 degrees F. are nearly double those when the jacket water is boiling. They also show that the losses increase very much more rapidly than in proportion to the speed, as is to be expected from the fact that they are due to fluid friction. These experiments were carried out for the author by Mr. L. G. E. Morse, of King's College, Cambridge.

Mr. Morse devised another method of getting the mechanical efficiency of a multi-cylinder motor, which, as it is very simple and appears to be quite accurate, is worth giving here. It consists in running the engine loaded with all the cylinders working. The load is put on by means of a Prony brake clamped to the flywheel, carrying a dead weight, which is partially supported by a spring balance having an open scale. The spring balance reads the excess of the dead weight over the brake load in the usual manner, and small changes in the brake

load may be very accurately read. In making a test one cylinder is stopped from firing by cutting off the current and the pressure on the brake blocks is reduced until the speed has come up to its old value. The reduction in brake load is then read off, and is approximately that corresponding to the indicated power of the cylinder which has been cut out. The four cylinders are treated in succession in this way, and by adding the results the indicated power of the engine is determined. Points obtained by this method with the corresponding jacket temperatures are shown by crosses (×) on Fig. 3, and it will be seen that they agree very well with those obtained by indicating only one cylinder.

The mechanical efficiency of this engine is remarkably high for its size. With boiling jacket water the mechanical efficiency is 90 per cent. at a speed of 400 revolutions per minute. It falls off to 75 per cent. at a speed of about 1,300 revolutions per minute. The thermal efficiency is also high, reaching over 26 per cent. under the most favorable conditions. The air-cycle efficiency corresponding to the compression ratio 3.85 is 41.5 per cent., so that the relative efficiency is 0.625.

Appendix I.—Description of Indicator.

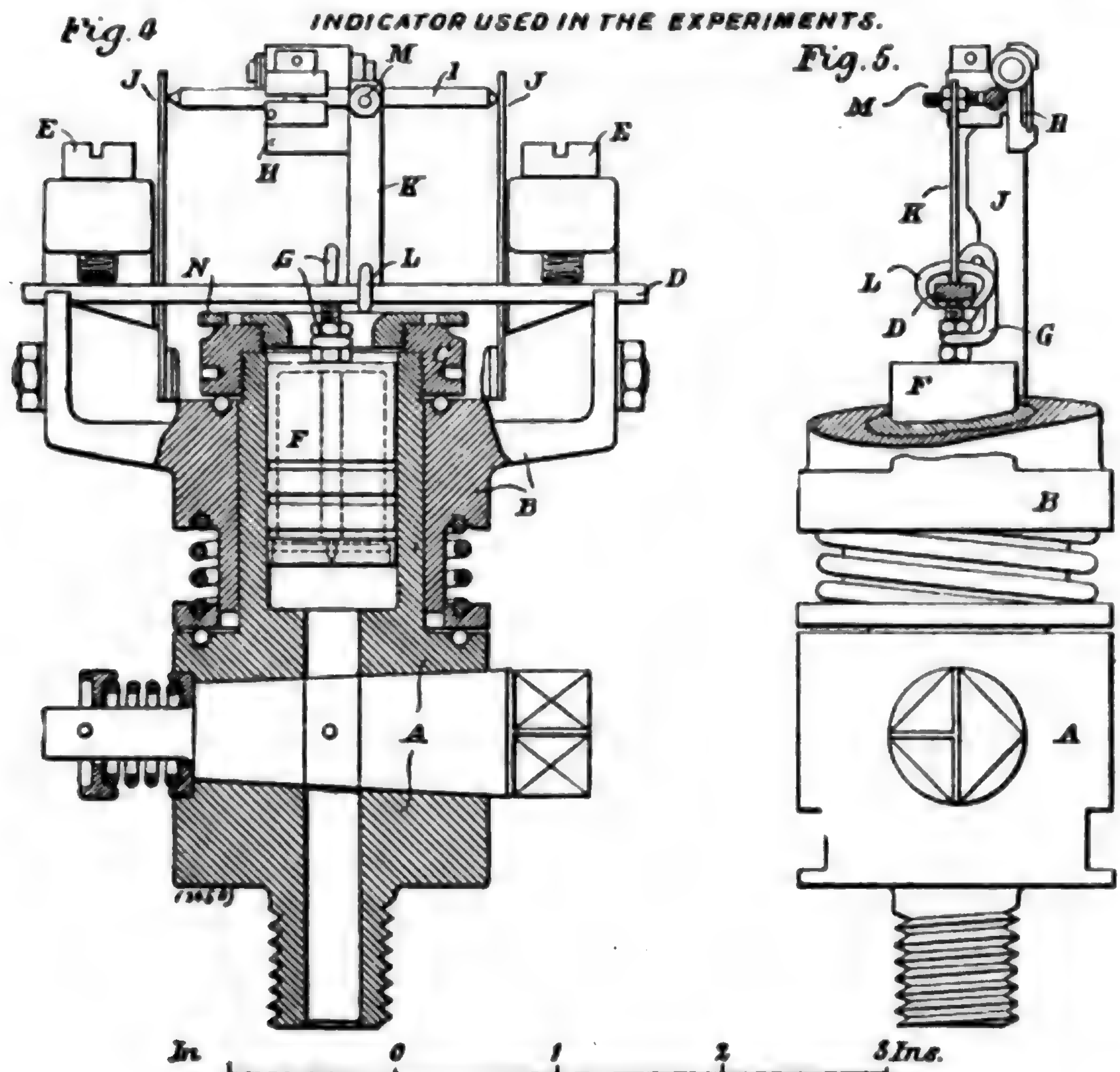
Fig. 4 is a drawing of the instrument, partly in section. The block A is screwed into the ordinary indicator hole of the engine. The frame B fits over the block, sufficient clearance being left to provide for unequal expansion. The frame is held up by a spring into engagement with the lower face of the nut C (screwed to the top of A), a ball race being interposed so as to admit of easy rotation of the frame about the axis of A.

The spring D is a piece of steel strip resting in grooves at the end of the frame B, and held by the screws E, E. This spring is slightly bowed before insertion in the frame, so that when the screws E, E are screwed home, the spring is held straight, with slight pressure on the four points of support.

The piston F slides in a bore in the block A. It is made hollow, but a plate closes its lower end. At the top it is provided with a hook G, the opening of which is slightly larger

than the thickness of the spring. The piston is thus free to move laterally, and no binding action is possible between it and the sides of the bore, such as would occur if the piston were rigidly attached to the spring.

The mirror H is clamped to a steel spindle I, the ends of which are pivoted in small holes in the vertical spring-cheeks J, J. The motion of the spring D is communicated to the



spindle and mirror by means of the piece of vertical spring K. The lower end of this piece of spring is held firmly on the face of the main spring D by means of the jaws L; the upper end is firmly clamped to the arm M which projects at right angles from the mirror spindle. (See Fig. 5, which is a section in a plane at right angles to Fig. 4.)

The spring K, while sufficiently rigid to transmit the motion

of the main spring to the end of the arm M without buckling, is flexible enough to allow for the angular motion of that arm. The mirror is thus turned about the axis of the spindle by an amount which is proportional to the displacement of the main spring D, and therefore to the pressure under the piston.

In order to give the other motion to the mirror the frame B is positively connected by linkage to a reciprocating part of the engine, and is thus caused to rock as a whole about the axis of the block A. The motion thus given to the frame B must be in phase with and proportional to the piston motion. In consequence of the smallness of the angular motion (about one-sixteenth of a radian) of the frame B, it is easy to secure this result with simple gearing, the effect of the curvature of the paths of the joints in the linkage being negligible. A convenient arrangement is that shown diagrammatically in Fig 6, in which S is an eccentric fixed to the crank shaft, and such that the diameter is to the throw as the crank radius is to the length of the connecting rod. The lever W is jointed at one end to the rod V, which takes its motion from one end of a lever pivoted at the other end T, and engaging with the eccentric by a roller J. At the other end, W is fixed to a clamping ring X, which fits over the turned portion of the frame of the indicator, Fig. 4.

The manner in which the diagrams are made visible is apparent from the diagram, Fig. 7.

Fig. 6. DIAGRAM OF LEVERS FOR OPERATING THE INDICATOR MIRROR

The source of light is a fine hole P illuminated by an ordinary four-volt incandescent lamp. The rays from this, after reflection from the plane mirror of the indicator Q, fall upon the

convex lens R_1, which is placed about 18 inches from the mirror, and is 4 inches in diameter. The focal length of this lens is about equal to its distance from the mirror, and the beam of reflected light is therefore refracted to a direction about parallel with the axis of the lens. The beam comes to a focus in the plane R_2, and traces out in that plane the indicator diagram of the engine, the vertical displacements of the spot (corresponding to the tilting of the mirror about the spindle) being proportional to the pressure, and the horizontal displacements (corresponding to the rocking of the indicator frame) to the piston motion. With a sufficiently powerful source of light this diagram could be made visible by a ground-glass screen placed in the plane R_2; but in order to render it visible with a

Fig. 7.

small lamp, a transparent screen is used and a second lens R_3 is interposed about 10 inches from R_2. This lens is of equal diameter with R_1, and refracts the beam of light (which before striking it is parallel to the axis) to its principal focus R_4, where the eye is placed. The beam is at the same time converted into a parallel beam, and the spot is seen sharply defined on the screen. The diagram traced by the spot is seen as a bright line of light. The screen is engraved with horizontal and vertical lines, on which the diagram is projected. The pressure at any point can thus be easily read off, or the diagram can be plotted down on squared paper.

Three pistons are used, the areas being in the ratio of 1, 2 and 4. There are two springs, which are ground so that the stiffness are in the ratio of 1 to 5. A wide range of sensibility is thus obtained. The smaller pistons fit inside liners which are inserted in the bore of the block A, Fig. 4. The spring is very easily changed by slacking the screws EE and slipping the springs out together with the spindle and mirror, the spring

cheeks JJ being slightly separated to allow of the spindle being taken out. When the spring has been removed, the piston can also be readily taken out by removing the cap N, Fig. 4, which serves also as a stop to prevent excessive bending of the spring.

The indicator is very easily calibrated by dead weights. The calibration is found to remain constant within 1 or 2 per cent. when the spring is removed and replaced. Suction pressures are registered on the same scale as those above atmosphere, on account of the slight initial set in the spring.

Appendix II.—Conditions Determining the Gas and Air Taken per Suction.

The total quantity of mixture drawn into the engine per suction is determined mainly by the temperature of the cylinder walls and piston, and is not affected much by the temperature of the gas left in the compression space from the previous stroke. This is most easily seen by supposing the incoming charge to be kept adiabatically separate from the residual gas. The total charge then drawn in will obviously be independent of the temperature of that gas. If, now, at the end of the suction stroke, when all valves are closed, the incoming charge and the residual gas are mixed, the pressure will not change. For the internal energy of a given volume of gas having constant specific heat is a function of its pressure, and is independent of its temperature or of the distribution of temperature in it. It can make little difference whether the mixing takes place at the end of the stroke, as supposed, or during the stroke, as, in fact, it does. In either case the quantity of gas drawn in is nearly independent of the temperature of that with which it mixes. The author believes that this was first pointed out by Mr. Dugald Clerk, in the Appendix to his paper on "The Limits of Thermal Efficiency in Internal-Combustion Engines."

It follows that in an engine governing by hit-and-miss, the amount of gas and air drawn in will be substantially the same after a miss as after an explosion. The ratio of gas to air in the charge taken in, and the quantity of gas, will also be much the same, provided that the opening of the gas cock and the

pressure outside be the same. Since, however, the incoming charge mixes with cold air instead of hot products, the weight of the total charge present in the cylinder at the end of suction will be greater, its temperature will be lower, and the percentage of gas present in it will be less. The diagram should therefore be unaffected except in so far as the weakening of the mixture improves the efficiency, and so enlarges the area. This should cause an enlargement of from 4 to 5 per cent., or considerably more than has usually been observed in the engine used for the tests described in this paper. The inference is that the gas supply is, in fact, rather less after a miss than after an explosion.

Fuller investigation of the matter shows that this must be so. Let

v = quantity of gas left in compression space;
t = temperature of gas left in compression space;
V = quantity of gas and air taken in;
T_1 = temperature of gas and air taken in before entering.
v_0 = volume of cylinder contents at completion of suction;
t_0 = temperature of cylinder contents at completion of suction;

the quantities of gas being expressed in standard cubic feet,* and the temperature on the absolute Centigrade scale.

Then at the commencement of suction we have V standard cubic feet of air and gas outside the engine at temperature T, and v inside at temperature t, all at atmospheric pressure p_0. Thus the stuff which is ultimately to form the total charge has at this point the energy $k\ (V\ T + v\ t)$, where k is the thermal capacity at constant volume, or 19 foot-pounds.

When suction is finished the stuff is all inside the engine, and it then has the energy $k\ (V + v\ )\ t_0$.

During suction work is done by the engine to an amount W, which can be calculated from the light-spring diagram. Some heat H is also received from the cylinder walls. Some of this

* That is, cubic feet reckoned under the standard pressure of 760 millimeters of mercury (14.7 pounds per square inch) and the standard temperature of 0 degrees C.

work goes to increasing the internal energy, and some is done against the atmospheric pressure. The latter item is equal to the pressure multiplied by the increase of volume of the stuff —that is, to

$$\left\{\frac{V(t_o - T)}{273} + \frac{v(t_o - t)}{273}\right\} p_o,$$

p_o being the atmospheric pressure in pounds per square foot.

Equating the net work done on the stuff plus the gain of heat to the increase of energy, we get

$$W - \left\{\frac{V(t_o - T)}{273} + \frac{v(t_o - t)}{273}\right\} p_o + H$$
$$= k(V + v)\,t_o - k(VT + vt).$$

Or, since $k + \dfrac{p_o}{273} = k_p$, the specific heat at constant pressure:

$$W + H = k_p\left\{V(t_o - T) + v(t_o - t)\right\}.$$

Now,

$$\frac{(V + v)\,t_o}{273} = v_o\,;$$

whence, substituting for t_o,

$$VT = -\frac{W + H}{k_p} + 273\,v_o - v\,t.$$

If V' be the actual volume (before entering) of the gas and air taken in, so that $V' = \dfrac{T}{273} V$, and if v_s be the stroke volume $\left(= v_o - \dfrac{t\,v}{273}\right)$, the last equation may be written:

$$V' = v_s - \frac{W + H}{k_p \times 273},$$

or the actual volume taken is less than the stroke volume by the quantity $\dfrac{W + H}{k_p \times 273}$.

The hotter the contents of the compression space, the less heat will be taken in from the cylinder walls during suction. The charge taken in after an explosion will therefore exceed that taken in after a scavenging stroke, the cylinder and piston temperatures being the same.

It is assumed in this calculation that the pressure is atmospheric at the beginning and end of the suction stroke. With good valve action this is sufficiently nearly the case; and when it is not so it is easy to make the necessary correction. A further assumption is that the whole entering charge comes in from the air and gas pipes. This is not quite true, since in most engines the exhaust valve remains open for some time after the suction stroke has begun, and some stuff may back in from the exhaust pipe.

In the engine on which these experiments were made the mean pressure in the suction stroke when taking both gas and air is 2 pounds per square inch. Thus,

$$\frac{W}{t_p \times 273} \text{ is } \frac{2 \times 144 \times v_s}{26.75 \times 273} = 0.04\, v_s$$

The volume drawn in is therefore reduced to 4 per cent. below the stroke volume on account of the work done on the charge in drawing it in. The substantial correctness of this result has been verified by actual measurement of the cylinder contents at the beginning and end of the suction stroke, the engine being motored round and sucking air only, so that there was but little exchange of heat between the gas and the cylinder walls. The temperature of the charge at each end of the suction stroke was measured by a platinum thermometer.*

The value of H cannot, of course, be calculated, but it is not difficult to measure the actual volume of air taken by means of an anemometer. Tests of this kind under various conditions were made on the Crossley engine, of which the following are the most important. In each case λ is the ratio of the

* "On the Measurement of Gas-Engine Temperatures," "Philosophical Magazine," January, 1907.

total volume of gas and air taken in per suction (V^1) to the stroke volume (v_s). The stroke volume is 1.26 cubic feet:

1. Engine motored round without firing, gas-cock shut, $\lambda = 0.87$.

2. Engine motored round without firing, gas-cock open, $\lambda = 0.90$.

3. Engine firing 80 per 100 cycles. Jacket 62 degrees to 69 degrees F. (16 degrees to 20 degrees C.), $\lambda = 0.87$.

4. Engine firing 87 per 100 cycles. Jacket 173 degrees to 200 degrees F. (78 degrees to 93 degrees C.), $\lambda = 0.825$.

In No. 2 H cannot have amounted to much, as the jacket and piston were both cold. About half of the 10 per cent. loss of volume is to be ascribed to the work done (W) as already explained, the other half is due to gas coming in from the exhaust pipe during the first portion of the suction stroke. In No. 3 the piston was hot because of the continual firing; it would have a temperature of at least 350 degrees C. (662 degrees F.). Thus H is considerable, and the result is seen in a reduced charge as compared with (2). In (4) H is further increased, and the charge is further reduced, by the hot jacket. It was found in these tests that the ratio of gas to air taken in varied somewhat, though the opening of the gas valve and the gas pressure were always the same. The range of variation amounted to about 5 per cent. on the ratio, and it could not be correlated definitely with any change in conditions. It takes place slowly, however, and does not affect the conclusion stated above as to the effect of a missed ignition on the charge of gas taken. It is probably due to changes in the temperature distribution in the engine, which would alter the relative amount by which the gas and air streams are warmed in coming in.

The anemometer was calibrated by motoring the engine round, the setting of the exhaust valve being altered, so that it opened at the out-center and closed a little before the in-center. The overlap of the exhaust and inlet-valves was thus reduced to about 7 degrees only, and the error due to air coming in from the exhaust pipe was practically eliminated.

Measurements of temperature (by platinum thermometer) and of pressure were made at the opening and closing of the inlet valve, and the cylinder contents at these points were thus determined. The calibration so made was accurate within 2 or 3 per cent. A somewhat similar method was used by the Institution of Civil Engineers' Committee; but they did not make any measurement of temperature. On this account their calibration was probably somewhat too high; perhaps as much as 5 per cent. For their purpose this was near enough, since they only required the total volume of air passed through the engine for the purpose of estimating the amount of a small correction in their heat quantities.

Appendix III.—On the Loss of Heat in Compression.

In this engine the pressure reached at the end of the compression stroke, when compressing air only, is 173 pounds per square inch absolute, with a normal barometer. The pressure at the closing of the inlet valve under the same circumstances is 0.15 pound per square inch above atmosphere, or 14.85 pounds per square inch absolute. The ratio in which the volume is reduced between the closing of the inlet valve and the completion of compression is 6.17. Assuming that there is no leakage, it follows that the absolute temperature is increased by the compression in the ratio $\frac{173}{14.85 \times 6.17}$, or 1.89. The rise of temperature is therefore $0.89\,\theta_0$ where θ_0 is the temperature at the beginning of compression. Assuming that the compression curve is of the form $pv^n =$ constant, the index n has the value of 1.35. As a matter of fact, n is less at the beginning of compression than at the end. The work done in compressing air according to the law $pv^{1.35} =$ constant, so that the volume changes in the ratio 6.17 would be sufficient (if there were no loss of heat) to raise its temperature in the ratio 2.14. This is most easily seen by noting that the curve $pv^{1.35} =$ constant is the adiabatic compression curve of a gas whose specific heat is $\frac{7.75}{0.35} = 22.2$ foot-pounds per standard

cubic foot. The temperature rise corresponding to compression in the ratio 6.17 is, as already seen, $0.89\,\theta_0$; and this is the rise of temperature produced in a gas of specific heat 22.2 by the work under the compression curve. The same amount of work, applied to heating air, would therefore raise its temperature by $\frac{22.2}{19} \times 0.89 = 1.04$ times θ since the specific heat of air is 19 foot-pounds. Since the actual rise of temperature of the air is $0.89\,\theta_0$, it follows that the heat lost in compression is such as would raise the temperature of the air by $1.04 - 0.85 = 0.15$ times θ_0. Thus about 14 per cent. of the work done in compression in this engine is lost to the cylinder walls. This result depends on the assumption that the compression curve has the form $pv^n =$ constant; but the result will not be greatly different if n varies somewhat during the compression stroke, provided that the pressure and volume at the beginning and end of compression are the same.

The mean absolute pressure of the compression curve (still assumed to be $pv^{1.35} =$ constant) is 3.03 times the initial pressure, or 45 pounds per square inch.

We have now to consider the expansion curve. If the expansion be assumed to be adiabatic, the pressure after expanding 6.17 times will be $\frac{173}{(6.17)^{1.41}}$ or 13.5 pounds per square inch. This is not far from the value actually observed by the indicator, and it is probable that very little heat is lost in the expansion. The mean pressure under the assumed adiabatic expansion curve is starting at 173 pounds per square inch and finishing at 13.5 pounds, just over 43 pounds per square inch. The mean pressure in the loop formed by the compression and expansion curves is therefore about 2 pounds per square inch.

H. M. S. *MOHAWK*.

The ocean-going torpedo-boat destroyer *Mohawk*, built by Messrs. J. Samuel White & Company, Ltd., of East Cowes, I. W., for the British Navy, ran an official trial on the Maplin

THE BRITISH TORPEDO-BOAT DESTROYER "MOHAWK."

Mile on Tuesday, November 5, obtaining a mean speed of 34.3 knots per hour. This is 1.3 knots in excess of the contract speed of 33 knots, which speed, considering the high basis speed, is a remarkable result, the oil-fuel consumption being very satisfactory.

The principal dimensions, etc., of the ship are: Length, 270 feet; displacement, 800 tons; armament, three 12-pdr. Q.F. guns, two 18-inch revolving torpedo tubes; speed to be maintained on a six-hours' full-power trial, 33 knots; radius of action at economical speed, 1,500 nautical miles.

The vessel is propelled by turbine machinery, comprising five turbines (three ahead and two astern), driving three shafts and propellers, built by Messrs. J. S. White & Co., Ltd., under license from the Parsons Marine Steam Turbine Co., Ltd., the machinery being of about 14,500 I.H.P.

Steam is supplied by six water-tube boilers, each of about 2,400 H.P., of the "White-Forster" type, made by the same firm, these boilers being fired by liquid fuel on a system which has been experimented with successfully by the Admiralty for some years.

No cold storage is provided in the vessel, as she will rely entirely on the liquid-fuel installation.—"Page's Weekly."

THE SPEED OF TORPEDO-BOAT DESTROYERS.

The trials which have recently been carried out in the torpedo-boat destroyers of the *Tribal* class have been remarkable for the ease with which the contract speed has been obtained, in spite of the limitations imposed. It will be remembered that a speed of 33 knots was to be maintained over a period of six hours, while the amount of fuel burned per square foot of heating surface per hour was limited; the fuel was oil, which these vessels are designed alone to carry. They were also required to have a radius of action of not less than 1,500 nautical miles at 13 knots. That these requirements, which in some respects are conflicting, have been carried out, and the contract speed exceeded in all the boats

of the class yet tried is a vindication, if such were necessary, of the value of oil as fuel in vessels designed for purely military purposes.

The limitation of the amount of oil burned per square foot of heating surface is, no doubt, wise, in view of the danger of local overheating, which is always a possibility when such fuel is used. The usual allowance of heating surface per indicated horsepower in water-tube boilers of the "Express" type, when used in conjunction with reciprocating engines, is $2\frac{1}{8}$ square feet, which means that at full power the average evaporation over the whole of the heating surface is about 8 pounds per square foot. As the evaporation is very unequally divided among the tubes, those nearest the fire accounting for a much larger part of the steam generated than those more remote, an average of 8 pounds is probably quite high enough, if the fire rows are not to be unduly stressed. When burning oil fuel there is a greater possible disparity between the work done by the fire rows and the remainder of the tubes than in the case of a coal-fired boiler. The maximum temperature of the oil jets is attained in a zone of comparatively small area a foot or so from the burner nozzle, and the boiler tubes in that vicinity effect a larger proportion of the evaporation than would be the case if the furnace temperature were more equally distributed. It may be assumed that the quantity of oil fixed as a maximum to be burned per square foot of heating surface is the result of the Admiralty experiments on the evaporative results to be expected per pound of oil in boilers of this type, and the mean evaporation per square foot of heating surface which it has been found advisable not to exceed. Such a limitation necessitates ample heating surface in order to make sure of the power required for the contract speed; but, on the other hand, every square foot added means extra boiler weight and extra displacement, and some reduction in the radius of action. Fortunately, it appears that there was ample margin in this respect, though it seems from the speeds obtained—in one case 2.36 knots above the contract—that the designers have erred on the safe

side as regards heating surface. These results, it may safely be assumed, are unattainable in similar vessels fired with coal, for, although the ill-fated destroyers *Viper* and *Cobra* reached equal speeds to those now realized in the *Tribal* class, they were not at their sea-going displacement, and had no limitations as to the amount of fuel to be burned. We believe, moreover, we are right in saying that the *Viper*, in the course of her short career on service, never approached her measured-mile performance. How much of the success is due to the turbines it is difficult to say. Possibly the equipment of such a vessel with reciprocating machinery of, say, 15,000 indicated horsepower on two, or even three, shafts would present insuperable difficulties within the limits of space and weight allowable, and taking also into consideration the straining actions due to the reciprocating forces on a comparatively light hull. Whether this mechanical problem is capable of solution or not, the superiority of oil fuel for the purpose of maintaining speed over a considerable period is abundantly demonstrated.

Two factors operate in the maintenance of speed when burning coal, the necessity of cleaning fires and the endurance of the stoker, neither of which has any significance when burning oil fuel. When burning coal at the rate of combustion required in these small-tube boilers for full speed, one or other of the furnace doors is practically always open for stoking, and the volume of cold air admitted must detract both from the efficiency of the boiler and its steam-giving capacity. An indifferent stoker, by keeping each furnace door open a few seconds more than necessary may, in the sum total of all the openings, make just the difference between a satisfactory and an unsuccessful trial. Oil burning still requires skill and intelligence on the part of the stoker, and perhaps of a higher order, but it does not entail that hard manual labor and constant supervision which makes a full-speed trial on a torpedo-boat destroyer burning coal more like a nightmare than an engineering performance. In one particular especially, the regulation of the boiler feed, the su-

periority of the oil-fired boiler is marked. Automatic feed regulators have not been a pronounced success in water-tube boilers of the small-tube type, and it is always necessary to supplement the working of the apparatus by manipulation of the feed-check valve, the amount of hand regulation depending upon the character of the stoking and the consequent steadiness or otherwise of the rate of evaporation. With oil fuel, once the burners are set the feed pumps can be adjusted to the evaporation with a reasonable certainty that no manipulation of the feed valve will be required. In a word, stability of working conditions on which maintenance of full speed depends is easy of attainment with oil fuel, while it is comparatively difficult, even with expert stoking, when burning coal.

The speeds obtained in the *Tribal* class, though remarkable, do not appear from the particulars available to be due to any increase in the propulsive coefficient; they are simply the logical result of being able by means of oil-fired boilers and turbine engines to maintain a high power which otherwise would not be within reach. It is not intended to minimize the importance of the results; they are a fitting culmination—if that point has yet been reached—of the experiments which have been carried out by the Admiralty at Portsmouth and elsewhere, on the use of oil fuel in naval boilers; and the success is all the more gratifying when it is remembered that several other Admiralties, after a study of the subject, have practically given up the quest. But while it is permissible that we should shake hands with ourselves on the results, two considerations should moderate our enthusiasm. The first is that we are still dependent upon foreign countries for our supplies of oil fuel, and the other is that these turbine-engined boats are admittedly still a long way behind those with reciprocating engines in fuel economy at cruising speeds. The first-class torpedo boats recently added to the Navy List—formerly called "Coastal Destroyers"—are able at 13 knots to steam about 36 nautical miles per ton of fuel oil consumed. This is just about the same as the earlier

30-knot destroyers, with reciprocating engines, burning coal. The torpedo boats are only about two-thirds the displacement of the destroyers, and it must be remembered that the former are using a fuel of 30 per cent. greater calorific value than the latter. It is true that on account of the difference in length 13 knots is a higher relative speed in the torpedo boat than in the destroyer; but, making every allowance for this, there is obviously a very considerable margin in economy at this speed in favor of the reciprocating engine. The radius of action of the torpedo boats referred to is only about 800 miles at 13 knots, that of the *Tribal* class of destroyers about 1,500 miles, while the earlier 30-knot destroyers burning coal had a radius of action of nearly 3,000 miles.

It is difficult to assign the relative importance of speed and radius of action. Speed is an offensive quality, but the necessity for its use may not arise till after many days' steaming at ordinary speed, and radius of action is, therefore, also an offensive quality. The two together are the modern equivalent of the weather gauge of Nelson's day, as the vessel having superiority in these respects can always choose to give or to decline battle. From the nature of our position it has always been necessary, and probably always will be necessary, for us to hold this advantage over our rivals. In "Before Port Arthur in a Destroyer," supposed to have been written by a Japanese naval officer in command of one of these vessels, there is much internal evidence of the value of radius of action. We read of the boats engaged in patrolling before Port Arthur coaling from a cruiser every twelve hours, and frequent mention of returning to a base to coal after only a few days at sea. In the battle of Tsushima the Japanese destroyers do not appear to have been in evidence till near the end, when they attacked the almost completely disabled Russian ships. Speed then was not of great importance, as the Russian ships could neither fight nor run away, but if the destroyers had been a day or two at sea they might not have had sufficient coal to deliver an attack at full speed had they desired to do so. Conditions such as these may operate in

any conflict in which our destroyers may be engaged, with the added disadvantage of increased distance from a base. Floating bases from which supplies of fuel may be obtained are, of course, a factor to be considered, but such vessels are necessarily slow in speed and require convoying, and they may, under certain conditions, hamper a fleet as much as help it. In the *Tribal* class, by sacrificing a knot in speed and putting the weight saved in machinery into fuel, the radius of action would be increased by about 300 miles. As we are now possessed of destroyers which in the matter of speed are much in advance of anything possessed by any other naval power it is worth considering whether sufficient attention has not, for the present, been paid to this quality, and whether more attention should not now be paid to increasing the radius of action by increase of fuel supply and improvement of economy of the propelling apparatus at the cruising speed.—"The Engineer."

H. M. S. *TARTAR*.

The official six-hours' full-speed trial of H. M. S. *Tartar*, one of the larger class of ocean-going destroyers recently built for the British Admiralty by Messrs. John I. Thornycroft & Co., Limited, Southampton, was satisfactorily carried out at the mouth of the Thames on Monday, December 16.

The speed obtained on the six runs over the measured mile was 35.672 knots, with mean revolutions of 775.5 per minute; while the mean speed obtained during the six hours was 35.363 knots, with mean revoluions 768.8 per minute. The highest speed attained on the measured course was 37.037 knots with the tide. The contract speed required by the Admiralty was 33 knots, so that it will be seen that this has been exceeded by 2.363 knots by the *Tartar*.

The table herewith gives the results obtained throughout the trial.

Fig. 1.—The "Tartar" Steaming at 34½ Knots.

Number.	Speed on six runs, in knots.	Mean speed during each hour.	Mean revolutions per minute on six hours.
1	36.810	35.137	763.9
2	34.549	35.245	766.2
3	36.961	35.401	767.9
4	34.286	35.301	767.44
5	37.037	35.429	770.2
6	34.286	35.665	775.4
Admiralty mean.	35.672	35.363	768.8

The following Admiralty officials were present: Engineer-Commander W. S. Frowd, Engineer-Commander L. J. Stephens, Engineer-Lieutenant E. J. Rosevere, Engineer-Lieutenant Rundle, and Constructors G. H. Ball, R. J. Grimshaw and H. G. White, Admiralty Overseer, and F. E. Hoe, Assistant Overseer; the firm of Messrs. Thornycroft being represented by the general manager, Mr. Callaway, and the technical directors, Messrs. S. W. Barnaby and T. Donaldson.

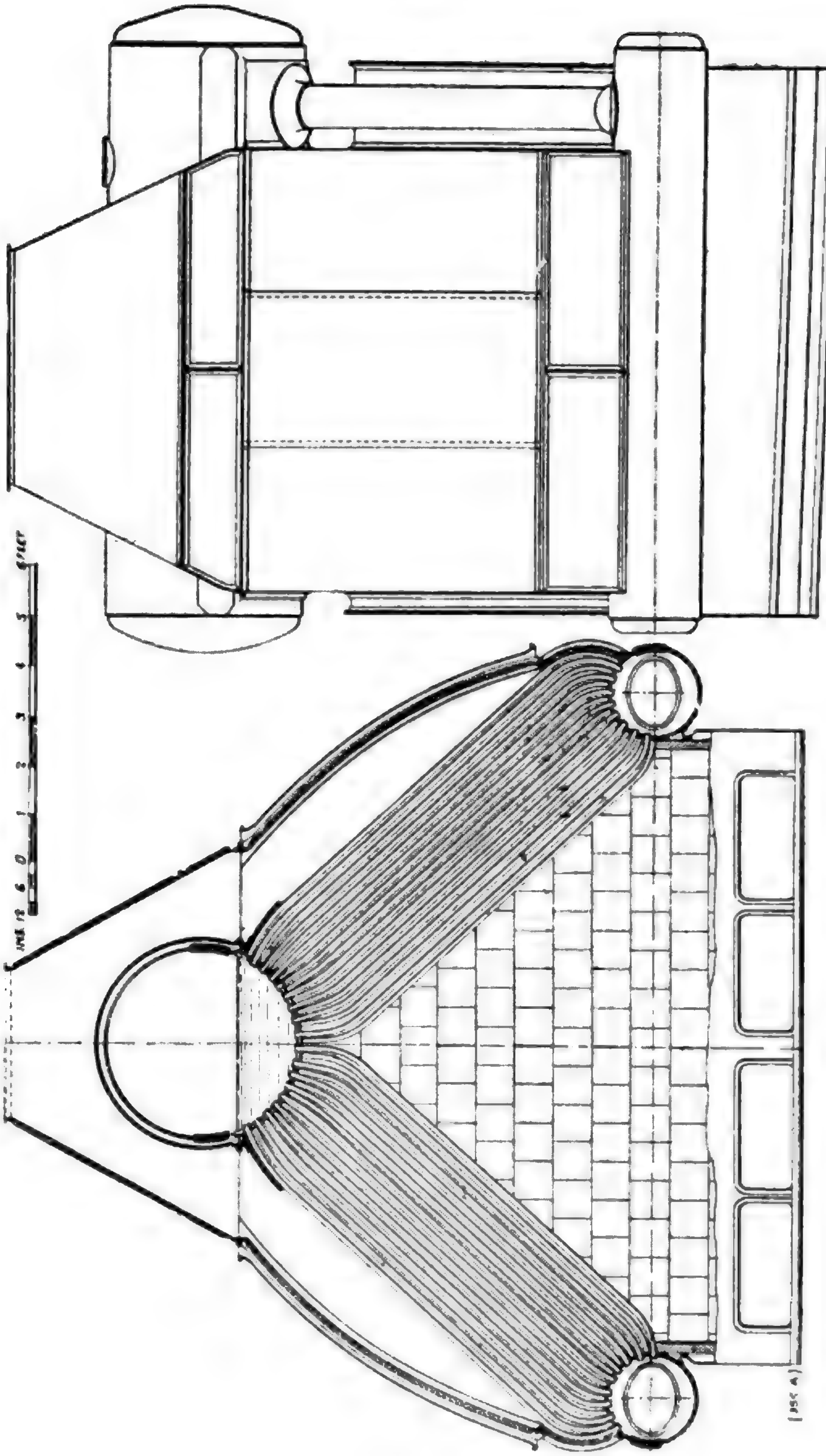
The splendid result achieved has been due to the employment of the latest advances in scientific marine engineering practice, together with the skill and special experience gained by the builders during the many years in which they have been engaged in building high-speed vessels.

The *Tartar*, which we illustrate in Fig. 1, is a vessel 270 feet long and 26 feet beam. She is built principally of high-tensile steel, and the methods adopted of constructing the hull are such as to obtain the maximum of strength for the least amount of material.

The propelling machinery (which was made by Messrs. Thornycroft & Co. at their Southampton works) is of the Parsons steam-turbine type.

The fuel used is a heavy oil, which is injected into the furnace by means of special burners of Admiralty pattern, and the boilers, one of which is shown in Figs. 2 and 3, are of the

Fig. 2. Fig. 3.



BOILERS OF H. M. TORPEDO-BOAT DESTROYER "TARTAR."

Thornycroft water-tube type (six in number). This combination provides a steady and ample supply of steam, the working pressure being 220 pounds per square inch.

As will be seen from the illustrations, the tubes are straight except at the ends where they enter the steam barrel and water barrels. It will be observed that the design lends itself well to the protection of the upper barrel from the fierce heat of the oil-fuel furnace. Each boiler has 5,300 square feet of tube surface; the fire-box tubes are 1⅜ inches in diameter and 10 L. S. G. thick, and the remainder are 1⅛ inches in diameter and 12 L. S. G. thick.

The advantages gained by using oil fuel are very apparent, as will be observed from the illustration (Fig. 1) taken from a photograph of the *Tartar* when running at 34½ knots in Stokes Bay, using oil fuel. It will be seen that from the funnels there is hardly a trace of smoke, which is due to the precision with which the necessary amount of air can be adjusted for perfect combustion. Another important matter is the freedom from the continual shower of small ashes from the funnels falling upon the deck, so usual in coal-burning ships, and the total absence of flaming at the funnels. Again, the ease with which the speed may be reduced almost instantly is a very important consideration.

The vessel will be fitted with wireless-telegraph apparatus. Mechanical means are provided for ventilating the engine room when the hatches are closed in bad weather. The usual system of voice pipes is replaced by an installation of loud-speaking telephones, fitted at all the important stations throughout the ship. The main deck is not obstructed by high coamings along the boiler rooms—an advantage due to the use of the Thornycroft type of boiler—and thus allows of easy passage from side to side.

The following is a list of a few of the torpedo boats and destroyers built by Messrs. John I. Thornycroft & Co., Limited, each of which created a record in its day:

Name.	Government.	Date.	Speed, in knots.	Type.
Ariele..................	Spanish	1887	26.003	Torpedo boat
Daring................	English	1893	28.213	Destroyer
Boxer....................	ditto	1894	29.170	ditto
Desperate............	ditto	1895	30.350	ditto
Albatross..............	ditto	1898	31.500	ditto

The total number of torpedo boats and destroyers built by this firm is 293, and the *Tartar* is the first one built and completed at the Woolston Works, where at the present time there are building the *Amazon*, which is a little larger than the *Tartar*, and four torpedo boats fitted with oil-fuel arrangements and the Parsons type of steam turbine, for the British Admiralty. Since the trial of the *Tartar* an order for a second *Amazon* has been received by the firm.—"Engineering."

NEW TURBINE STEAMERS FOR THE MEDITERRANEAN.

January 18, saw the departure from the Clyde, after a most successful series of trials, of the new turbine steamer *Cairo*, built along with the sister ship *Heliopolis*, by the Fairfield Shipbuilding and Engineering Company, Ltd., for the Egyptian Mail Steamship Company's express service between Marseilles and Alexandria. The trials of both vessels, which were carried out at load draught during the stormy days of November and January, resulted in the attainment and continuance of a speed of over 20½ knots, which is exceptionally high for vessels of their dimensions and passenger capacity. During the trip from the Clyde to Plymouth, the *Heliopolis*, in the Irish Sea, kept up the remarkable speed of 21.9 knots for a period of three hours, and had to be slowed down to avoid arriving too early at Plymouth, where arrangements had been made for her reception. From Plymouth to Marseilles she again showed her qualities as a racer, covering the distance in the record time of 95½ hours, while on her first voyage the distance from Marseilles to Alexandria was covered in 72½ hours, and on the return trip she gave clear indica-

tions that, barring unfavorable weather conditions, she can still further reduce the time between these points.

Passengers on the *Heliopolis* report the behavior of the vessel to be all that could be desired. The absence of vibration in any part of the vessel is notable, and bears testimony to the care and skill shown by the builders in the balancing and arranging of her machinery and propellers and in the stiffening and pillaring of her structure. The ease of her pitching motion when the wind and sea were ahead, and of her rolling with a beam sea, made it difficult to believe that one was really at sea at all, when in a cozy deck stateroom. Even when facing a gale of such violence that it was considered advisable to slow down to 10 knots to prevent danger of carrying away any of the forward-deck gear, the passengers were able to dine in comfort without having recourse to "fiddles," and with no risk of wine spilling.

The *Heliopolis* and the *Cairo* have a period of roll of about 20 seconds, which is remarkably and unusually long for vessels of their dimensions; and this fact together with the general excellence of their arrangements, make the voyage seem all too short for the full enjoyment of the many pleasures afforded. The dimensions of these two vessels, upon the possession of which the Egyptian Mail Steamship Company, Limited, are to be congratulated, are as follows: Length over all, 545 feet; breadth, 60 feet 3 inches; depth from keel to shelter deck, 38 feet; tonnage, 12,000 tons gross; horsepower, 18,000; mean speed on 12-hours' trial, 20.6 knots.

The hull is subdivided into ten compartments by transverse bulkheads, with cellular double bottom right fore and aft. There are seven decks—boat, promenade, bridge, shelter, upper and main decks.

Extensive stateroom accommodation is provided for a large passenger list, and this and the public rooms are, alike in dimensions and decoration, close imitations of the best practice in Atlantic steamship building. The first-class passenger public rooms include a café on the boat deck, a music room

on the promenade deck, a library and smoking room on the bridge deck, and dining saloon on the shelter deck. The second-class public rooms include a smoking room, social hall and dining saloon on the shelter deck. A prominent feature is the extensive promenade space provided on the three decks above the molded dimensions of the ship. Ventilation, too, had special consideration.

The machinery is of the Parsons type, driving three screws. The center propeller is operated by the high-pressure turbine, and the two wing propellers by the low-pressure turbines, the astern turbines being fitted also to the wing shafts. Full power is developed when the engines are making 340 revolutions.

A series of progressive-speed trials was made by each ship. For 200 revolutions the speed was 12.198 knots; for 261 revolutions, 15.419 knots; for 314 revolutions, 18.16 knots; for 346 revolutions, 19.83 knots; and for 372 revolutions, 20.75 knots. Following upon this trial the vessels, at full draught, had to be run for twelve hours at full speed. The *Heliopolis*, with a draught of 21 feet 5½ inches, made 20.53 knots for 366.3 revolutions, while the *Cairo*, with a draught of 22 feet, made 20.6 knots for 372.5 revolutions. But when we publish our detailed article on the ships we shall be able to deal with these trials in greater detail.—"Engineering."

NEW TORPEDO CRUISERS FOR TURKEY.

The illustration given herewith shows one of the two new Turkish gunboats, the *Peit-i-Shevket* ("His Majesty's Messenger") and the *Berc-i-Satvet* ("The Lightning of Force"), which were laid down at the end of 1906 and delivered in the month of October last, after a series of satisfactory trials. The *Peit-i-Shevket* and her sister ship, which were built by Fried. Krupp, A. G. Germaniawerft, Kiel, are now on their way from this harbor to Constantinople. On general lines they embody an improved design of the old tor-

Turkish Torpedo-Boat Cruiser "Peit-i-Shevket."

pedo gunboats *Pelenk-i-Deria* and *Namet.* Their principal dimensions are: Length, 262 feet; breadth, 27 feet 6¾ inches; draught, 8 feet 2¾ inches. Their displacement in normal load condition is about 740 tons, their coal supply 240 tons. At speed trials they attained one knot more than the contracted 22 knots. They are armed with two 10.5-cm. (4-inch), six 5.7-cm. (2¼-inch), two 3.7-cm. (1½-inch) guns, all Krupps, and five Hotchkiss quick-firing guns. Torpedo armament: One bow tube and two deck tubes, one on each broadside, all for 18-inch torpedoes.—"Engineer."

THE ITALIAN BATTLESHIP *REGINA ELENA.*

The designer of this class is Colonel Cuniberti, of the Corps of Italian Naval Constructors, who was probably the first to put forward the idea of a very fast and heavily-armored battleship provided with a uniform 12-inch armament. A very casual inspection of the *Regina Elena* is sufficient to convince anyone that Colonel Cuniberti's genius does not stop at imaginary *Dreadnoughts.* The ship is only of 12,625 tons displacement, but in the very fact of this small displacement lies the marvel. She is quite the last word in economy of weights and utilization of space. Nor does she stop there. Under the big-gun turrets a novel girder construction is introduced to take up the stress of firing, and the success of this may be gauged from the fact that all possible guns have been fired ahead, astern and on the broadside without the slightest inconvenience to the vessel.

The armament is as follows: Two 12-inch 45-caliber (Armstrong); twelve 8-inch, 45-caliber; twelve 12-pounders; twelve 3-pounders; four Maxims; four 18-inch submerged tubes (Elswick patent).

The 12-inch guns, which are very similar to the *Dreadnought's* pieces, are carried in cradle mountings similar to those adopted for our new *Dreadnoughts.* The turrets, placed fore and aft in the center line, are extremely roomy. Each

carries a single gun only. This is the most criticised feature of the ship; but it should be borne in mind that a pair of guns in a turret do not make twice as good shooting as a single gun, and—sacrifices being necessary on the displacement—this was probably the wisest that could be made. These 12-inch and also the 8-inch guns are all electrically maneuvered; all hoists also are electric. The big-gun turrets are placed quite clear of all upper works, and have an enormous arc of training, something like 300 degrees, instead of the usual 240 degrees or less. In many positions, therefore, the ship can deliver as much 12-inch fire as the usual four big-gun ship; the 8-inch turret bases extend down to the armored deck, everything being extremely roomy.

The 8-inch guns are carried in pairs in six turrets amidships, the central turrets being raised so as to fire over the end turrets. Eight 8-inch guns can, therefore, fire ahead and have been actually so fired without any inconvenience to the guns fired over. There are no fittings of any sort or kind in the way of these guns, but a perfectly smooth floor ahead and astern. Each upper turret has an actual arc of 180 degrees, the others 135 degrees. The bases of all are heavily armored, and have also armored splinter screens, and there is no diminution of thickness on the inner side.

Eight of the 12-pounders are carried in the amidships battery behind 3¼-inch armor, the remainder, two about the conning tower and two on the similar topside aft.

Fire control is from the top of the conning tower, where there is a heavily-armored station. It is not so suitable, perhaps, as the mast platform of the British Navy, but practically invulnerable, which mast stations are, undeniably, not. Barr and Stroud instruments are now being fixed. The whole of the necessary wires are carried down in a thickly-armored tube, and unlikely to suffer any injury.

The armor protection generally is very great. There is a 10-inch water-line belt amidships, thinning to 6-inch under the turrets and 4-inch at the extremities. It is surmounted amidships by an 8-inch redoubt approximately 160 feet long,

side and bulkheads being of uniform thickness. Thin armor is carried forward to the bow from this redoubt, protecting the whole lower deck. Above the redoubt is the 3½-inch 12-pounder battery. The conning tower is 10 inches thick and built in stories reaching down to an underwater control station. There are also stations in the forward big-gun turret and the two amidships 8-inch turrets. Great use is made of coal protection in addition to the armor. Normally the ship carries 1,000 tons, but there is room for no less than 2,800 tons.

The principal interest of the *Regina Elena*, however, lies in the engineering department. She is the fastest battleship in the world, being a good deal swifter than even the *Dreadnought*, with which ship, by the way, she shares the peculiarity of a greatly overhung stern. She is 475 feet over all, against 435 feet between perpendiculars.

The propelling machinery, manufactured by the firm of Odero, of Sestri Ponente, consists of two sets of four-cylinder, vertical, inverted, triple-expansion engines, balanced on the Yarrow, Schlick and Tweedy system. These engines are a very fine piece of workmanship. The engine rooms are as roomy as in our big ships. Instead of two large condensers four of medium size are fitted, and appear to be very satisfactory. The dynamo room is also amply large, the switchboard being mounted on a platform high up and clear of everything —there is none of that cramping which might, perhaps, have been expected.

Steam is supplied by twenty-eight Belleville boilers, designed to give 20,000 horsepower. They are in three groups —two of ten each, and one room of eight. These Bellevilles are of a considerably more modern pattern than those with which we are usually familiar in British warships. In main features they do not differ from those in our *Drake* and *Duncan* classes, but there are many refinements of detail. They are, of course, free from that loss of water which characterized our earliest Bellevilles, but that applies equally to any of our more modern ships so fitted. One detail is that the

tubes do not bend to any appreciable extent. In the *Regina Elena*, after one thousand five hundred hours' steaming, the bend in no tube exceeded one millimeter, and there has been a total absence of anxiety about the screw joints. The performance of the boilers on trial is said to have been extremely successful, and apparently this is correct, since Italy, which, after our Boiler Committee's decision, also discarded Belleville generators, has now re-adopted them and ordered this type for all three of the ships recently laid down—*Pisa*, *Amalfi* and another unnamed.

The designed speed of the *Regina Elena* is wrapped in some mystery, as it is variously given as 20 knots, 21 and 22 knots. The contract speed appears originally to have been 22 knots, reduced to 21.5 after the decision to fit this vessel and the *Vittoria Emanuele* as flagships, which involved a good deal of additional weight on the top sides. The other two ships of the class, the *Napoli* and *Roma*, will not be so fitted, and are expected to be about half a knot faster in consequence of this and other weight reductions.

On trial at three-quarter power the *Regina Elena* developed 15,473 indicated horsepower and a speed of 20.33 knots. On the full-power trial about 23,000 horsepower was developed, and the speed was 21.7 knots. For short runs this was slightly exceeded, but 21.7 seems to be about the maximum speed of the ship. On subsequent service trials it was found that with twenty-five boilers alight she could quite comfortably maintain 20 knots for any length of time. The economical speed is 15 knots.

In conclusion, it may be mentioned that the magazines are fitted with special refrigerators to maintain an even temperature of 20 degrees centigrade. There is practically no uncovered wood anywhere in the ship, all the cabin furniture being made of Uralite or some similar asbestos compound. Cupboards, tables and so forth are all of this material, so that there is practically no risk, whatever, of fire in action. The ship is fitted with wireless-telegraph instruments of the usual Marconi type.—"The Engineer."

STEAM TRIALS BRITISH ARMORED SHIPS IN 1907.

Name of vessel	*Agamemnon.*	*Warrior.*	*Minotaur.*	*Shannon.*
Type of ship	Battleship	First-class armored cruiser	First-class armored cruiser	First-class armored cruiser
Builders of ship	Beardmore	Pembroke	Devonport	Chatham
Makers of machinery	Hawthorne, Leslie & Co.	Wallsend Slipway Co.	Harland & Wolff	Humphrys, Tennant & Co.
Displacement, tons	16,500	13,550	14,[illegible]00	14,600
Type of boilers	Yarrow	Yarrow and cylindrical	Babcock & Wilcox	Yarrow
Heating surface, square feet	50,265	55,334–11,427	73,284	80,494
Grate area, square feet	848.7	971.1–365.4	2,083.8	1,365
First 30 Hours' trial:				
Indicated horsepower	3,494	4,781	5,643	5,849
Speed, knots	11.79 M. M.	14.7 bearings	14.107 M. M.	14.39 M.M., 14.529 throughout the trial
Coal per I.H.P. per hour, pounds	2.15	2.01	1.74	1.96
Water per 1,000 I.H.P. per 24 hours, tons	2.28	3.6	2.9	2.26
Second 30 hours' trial:				
Indicated horsepower	12,023	16,361	19,750	19,621
Speed, knots	17.037 M. M.	20.7 M. M., 19.96 throughout the trial	21.471 M. M., 21.4 bearings	20.92 M.M., 20.765 throughout the trial
Coal per I H H. per hour, pounds	1.9	2.06	1.63	1.83
Water per 1,000 I.H.P. per 24 hours, tons	1.76	3.01	[illegible]	1.733
Eight hours' full-power trial:				
Indicated horsepower	17,285	23,705	27,856	28,553
Speed, knots	18.735 M. M.	22.46 M.M., 22.409 throughout the trial	23.01 M. M.	22.49 M.M., 22.6 bearings
Coal per I.H.P. per hour, pounds	2.14	2.33	1.59	2.01
Water per 1,000 I.H.P. per 24 hours, tons	1.56	3.1	1.2	2.[illegible]

M. M. = Measured Mile.

TRIALS OF OCEAN-GOING TURBINE-DRIVEN TORPEDO-BOAT DESTROYERS IN 1907.

Name of of vessel.	Type of vessel.	Builders of vessel and makers of machinery.	Type of boilers.	Heating surface.	Speed on six hours' run.
				Square feet.	*knots.*
Cossack	Ocean-going t. b. d.	Cammell, Laird & Co.	Laird	29,000	33.144 M. M. 33.09 six hours
Tartar	Ditto	Thornycroft	Thornycroft modified	31,800	35.672 M. M. 35.36 six hours
Ghurka	Ditto	Hawthorn, Leslie & Co.	Ditto	27,550	33.997 M. M. 33.91 six hours
Mohawk	Ditto	J. S. White & Co.	White-Forster	29,580	34.5 M. M. 34.245 six hours

TRIALS OF FIRST-CLASS TURBINE-DRIVEN TORPEDO BOATS (NEW TYPE) IN 1907.

Number of boat.	Builders of boat and makers of machinery.	Type of boilers.	Heating surface.	Speed on eight hours' run.
			Square feet.	*Knots.*
3	J. S. White & Co.	White-Forster	8,000	27.077 M. M. 26.385 eight hours
4	Ditto	Ditto	8,000	27.077 M. M. 26.235 eight hours
5	Ditto	Ditto	8,000	27.521 M. M. 26.796 eight hours
8	J. I. Thornycroft & Co.	Thornycroft modified	8,200	27.084 M. M. 27.197 eight hours
9	Ditto	Ditto	8,200	27.196 M. M. 26.734 eight hours
10	Ditto	Ditto	8,200	26.182 M. M. 26.265 eight hours
11	Yarrow & Co.	Yarrow	8,004	27.163 M. M. 27.000 eight hours
12	Ditto	Ditto	8,004	27.206 M. M. 26.814 eight hours
23	Ditto	Ditto	8,004	26.796 M. M. 26.723 eight hours

SHOOTING IN THE BRITISH NAVY.

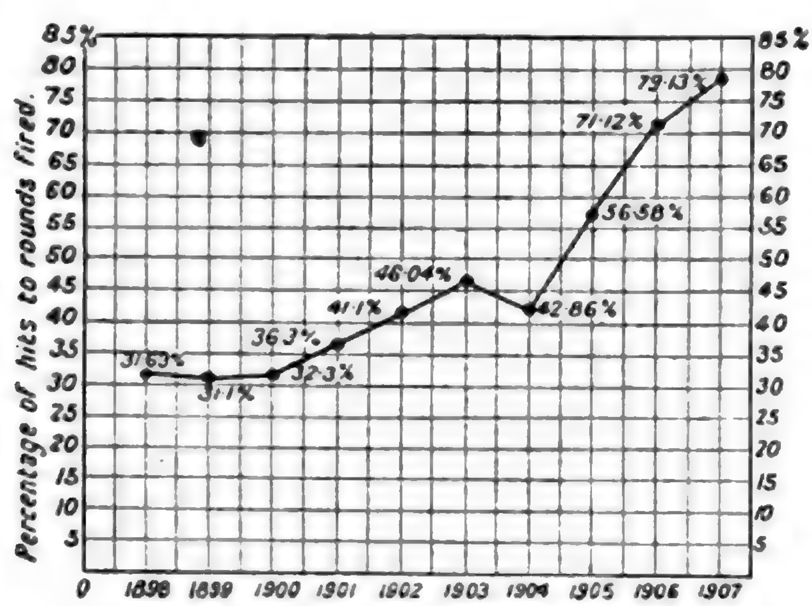
Three blue books have recently been issued by the Admiralty, entitled "Result of Test of Gunlayers with Heavy Guns;" "Result of Test of Gunlayers with Light Q.F. Guns;" and "Result of Battle Practice with Torpedo-boat Destroyers," respectively, for the year 1907. In each of these satisfaction is expressed in varying terms at the improvement shown as compared with former years.

Taking the heavy guns first, we find that as a total 121 ships fired in the trials, and that 1,365 guns were employed, these figures comparing with 89 and 1,073, respectively, for the year 1906. The following table gives the results obtained in those two years:

	1906.	1907.
Number of hits	5,733	7,547
misses	2,328	1,991
Total rounds fired	8,061	9,538
Percentage of hits to rounds fired	71.12	79.13

It will be observed from this that although in 1907 there were nearly 1,500 more rounds fired than in 1906 there were over 330 fewer misses, which is a very excellent performance. The last two years have witnessed a vast improvement in the shooting of the Navy, as may be seen from the following table:

Year.	Percentage of hits to rounds fired.
1898	31.63
1899	31.1
1900	32.3
1901	36.3
1902	41.1
1903	46.04
1904	42.86
1905	56.58
Mean	39.74
1906	71.12
1907	79.13



PROGRESS OF NAVAL SHOOTING

It will be observed that the mean of the eight years from 1898 to 1905, inclusive, was 39.74, which is very little more than half the figure obtained last year. It will be observed, further, that, with the exception of a small set back in 1904, there has been a continuous improvement ever since 1899, and that latterly the progress has been very rapid indeed.

The results will probably be better appreciated from the annexed diagram, in which the ordinates represent the percentage of hits to rounds fired in each year.

A new form of target was tried for the first time in 1907, and figures are given showing the comparative practice with the two targets during the year. The reports do not state specifically how this was done, but apparently the 1906 target was used, and a smaller target, which we will call the 1907 target, was marked upon it. The smaller target, of course, modified the results, and this again will be best shown by a table:

	1906 target.	1907 target.
Number of hits	7,547	4,073
misses	1,991	5,465
Total rounds fired	9,538	9,538
Percentage of hits to rounds fired	79.13	42.70

Even with the smaller target, however, the percentage of hits to rounds fired was more than the average with the larger target during the eight years from 1898 to 1905.

Some further details are given regarding the number of hits per gun per minute with different types of gun. These are collected in the following table:

	Target.	Hits per gun per minute.
12-inch and 10-inch	1906	.61
	1907	.40
9.2-inch	1906	3.25
	1907	2.01
7.5-inch	1906	3.48
	1907	1.58
6-inch Q.F. and B.L.	1906	5.93
	1907	3.32
4.7-inch and 4-inch Q.F.	1906	5.73
	1907	2.38

There are several points to be noticed regarding these figures. The first is that there is a slight falling off in the practice made by the 12-inch and 10-inch guns, as compared with 1906, the figure for the latter year being .81. This figure was, however, almost abnormally high, as the average for the nine years, from 1898 to 1906 inclusive, was only

43.71. The 1907 figure shows a satisfactory increase on this. Another point worthy of notice is the excellent practice made with the 9.2 guns. In 1906 the number of hits per gun per minute was 2.84; and in 1905, 1.40. For the seven years previously the number had never risen above .73, and the average was just under .41. The 1907 figure is nearly eight times better than this average. The 9.2-inch gun was also wonderfully successful with the 1907 target—even more so, in fact, than the 7.5-inch gun. Both the 6-inch and the 4.7-inch guns show satisfactory increases in the number of hits per gun per minute, the 1906 figures having been 5.68 and 4.96 for the two types of gun respectively. In both cases there has been a practically continuous improvement since 1898, when the figures were 1.11 and 1.68, respectively.

Turning now to the test of gun layers with light, quick-firing guns, the results of the three years 1905–6–7 are given in the following table:

	1905.	*1906.*	*1907.*
Number of ships that fired	86	89	122
guns	1,118	1,421	1,898
hits	2,228	4,666	7,462
misses	8,291	8,845	10,272
Percentage of hits to rounds fired	21.63	34.53	42.08
Hits per gun per minute, 12-pounders	2.12	3.417	4.471
6-pounders and 3-pounders (except Vickers)	1.97	3.358	3.64
Hits per gun per minute, 3-pounders (Vickers)	...	8.144	6.14

Very little comment regarding this is required. The number of misses is undoubtedly large, but on the other hand the percentage of hits to rounds fired shows a satisfactory increase, and is, indeed, very nearly double what it was in 1905.

An interesting comparison may be made between the figures in the foregoing table and those given in Blue book dealing with the result of battle practice from torpedo-boat destroyers. These are set out in the following table, the years 1905–6–7 again appearing:

	1905.	1906.	1907.
Number of ships that fired	57	52	121
guns	342	312	669
hits	653	1,004	2,069
misses	2,608	1,898	3,709
Percentage of hits to rounds fired	20.02	34.6	35.81
Hits per gun per minute, 12-pounders	1.54	2.43	3.97
6-pounders	1.98	3.73	3.57

The 1907 figures do not in this case show the same improvement, and it is rather a pity that no details are given regarding the relative conditions under which the tests were made.

Space does not permit of us going further into the contents of these Blue books, but the detailed data regarding the performances made by each particular vessel taking part in the tests are of much interest.—"The Engineer."

ITALY'S PROGRESS IN SUBMARINE NAVIGATION.

It is not commonly recognized how rapid and brilliant have been Italy's strides in the direction of submarine navigation. While most other nations engaged in like work have permitted a good deal of spectacular publicity, Italy has gone along in a quiet and unobtrusive manner with some experiments that have quite revolutionized the accepted standards in this fairly new branch of naval architecture.

From the first Italy has stood for the submersible, and the boats now possessed by Italy are typical of all that is best in this particular type of under-water craft.

The *Delfino* was the first of Italy's modern submarines. She was built in 1889. At that time she was a cigar-shaped craft, propelled by electricity and fitted with two 14-inch torpedo tubes. Her speed on the surface was not more than five knots, and when submerged she could not exceed a speed of two knots. To enable the boat to sink on an even keel and, in fact, to control her submergence, she was fitted with a couple of propellers set in vertical tubes running through

the boat, somewhat after the plan adopted by Nordenfelt in his boat built for the Russian Government—generally known as *Nordenfelt IV*.

While the results obtained with the *Delfino* in her original form were not altogether satisfactory, still she provided a fund of practical data which was properly estimated by the Italian authorities, and afforded a safe foundation for further development and trials. From 1889 until 1901 the *Delfino* was used for extensive experimentation, the results of which were carefully kept secret by all the officials concerned. In 1902, or thereabouts, the *Delfino* was considerably modified and underwent extensive improvements in a number of directions. As originally built, her upper-hull plating was made considerably heavier than the rest of her spindle-shaped body. In rehabilitating the craft, this heavy hull plating was removed and a great saving in weight thus effected, which was promptly put to better and more telling use in other directions. A set of up-to-date accumulators were installed in place of the old battery, and explosion motors were provided for the purpose of supplying power for surface propulsion. This gave the *Delfino* dual means of propulsion, the electric power being for submerged work only. The spindle-shaped hull had proved an undesirable form for surface navigation, and to make the boat more weatherly she was fittted with a superstructure something after the fashion of that now fitted on the British and American boats of the *Holland* type. Thus modified and modernized, the *Delfino* possessed a surface speed of 8 knots and a submerged speed of something over 6 knots. Two 18-inch torpedo tubes supplanted the two old 14-inch tubes, and altogether the *Delfino* has since shown herself to be an efficient and reliable craft.

The valuable information secured in the gradual evolution of the *Delfino* formed the groundwork upon which Engineer Cesare Laurenti worked in designing his boats of the *Glauco* type, which were launched successively in 1905, '06, '07. These vessels are 118 feet long, have a maximum beam of a trifle over 13 feet, and a surface displacement of 150 tons.

They are said to have developed a speed of 14 knots when running light upon the surface and a speed of 8 knots when running submerged. In the summer of 1906 these boats took part in the Italian naval maneuvers, and their performance was highly satisfactory during their work both by day and by night. Their mobility was amply demonstrated during the run from Venice to Taranto, which they made without convoy and entirely under their own power. Their part in the maneuvers consisted principally in making attacks upon anchored ships guarded by a large flotilla of torpedo craft. The *Glauco* and *Squalo*, while running at depths of from 10 to 20 meters, experienced no difficulty in passing through the narrow strait of San Vito and reaching the anchored battleships without once being detected by the guarding flotilla. These achievements, and the facility with which the boats were handled after only a short period of training on the part of their crew, gave the amplest evidence of the degree of perfection reached in their design and construction. It is the best sort of proof that the submerging boat in contradistinction to the diving boat is by far the easier craft to learn to handle; and this point has an important bearing upon the wartime usefulness of such vessels, when rapid changes or substitution in the crews may become necessary, and the ease with which a stranger may take up this work will mean everything to the military usefulness of such craft. An Austrian technical journal, commenting upon the performance of the *Glauco* and *Squalo* during the Italian manuevers, had this to say:

"The results achieved with the submarine boats at Taranto have confirmed the trials made with these vessels at Venice, and have shown that they are capable, especially by night, of approaching moored objectives and getting within an effective firing range of 800 meters. Furthermore, the performances at Taranto, have also proved that the Italian submarine craft possess exceptional firing apparatus for their torpedoes; and, in fact, it may be rightly claimed that the Italian Navy has made more progress in submarine navigation than any of the other first-class Powers, not even excepting France."

Coming from an Austrian critic this praise is very significant, because, when not acting upon the defensive, these Italian submersibles could have for their objective no other purpose than to attack the Adriatic ports of Austria.

In addition to the *Glauco* and *Squalo*, the Italian Government now has three other sister ships, namely, the *Narvalo*, the *Otaria* and the *Tricheco*. With these vessels the Italian Government has been recently carrying on a further series of experimental maneuvers, and from authoritative sources it is learned that their performances have served still further to emphasize the advanced position taken by Italy in the direction of submarine navigation.

Engineer Laurenti now has other boats under construction for the Italian Government, as well as for some northern countries. These boats are being built at Spezia, at the shipyard of the Fiat San Giorgio, the latter yard having gone in for specialization in the matter of submersible torpedo boats.

Some very interesting details regarding these vessels have leaked out, and this material is well worth reproduction. The following are their principal dimensions and general characteristics:

Length over all, feet and inches	139–04.5
Beam, extreme, feet and inches	16–10
Freeboard (hull), feet and inches	3–11.25
(hatch coamings), feet and inches	5–04.75
(to top of conning tower), feet and inches	10–09.75
Draught (surface trim), feet and inches	6–10.5
Displacement, surface, when fully laden, tons	180
submerged, tons	230
Safety drop keel, tons	12
Reserve buoyancy, in light condition	60 per cent. of displacement.
Metacentric height, surface trim, inches	19.6
submerged, inches	11.8
Number of bulkheads	8
Hull designed to withstand submergence to depth of, feet	150
Maximum power of explosion motors, horsepower	750
electric motors, horsepower	190
Number of propellers	3
Surface speed, maximum, knots	15
Submerged speed, maximum, knots	9
Surface radius of action at 8 knots speed, nautical miles	875

Submerged radius of action at 5 knots speed, nautical miles......	40
Total fuel capacity, cubic feet..	296.6
Compressed air in reserve, at 2,100 pounds pressure per square inch, cubic feet..	13,773
Number of air compressors..	2
Number of centrifugal pumps (for water ballast).....................	2

Each pump can discharge 130 tons per hour at a depth of 130 feet.

Each pump is driven by a special motor.

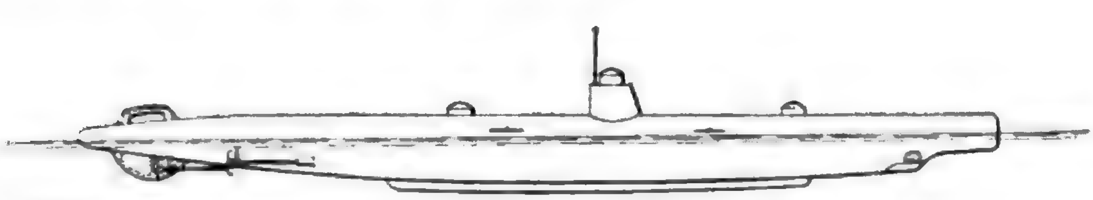
(1) *Speed.*—The best French boats do not exceed a surface speed of 12 knots, and this applies to vessels of 400 tons. The British boats of 300 tons of the C class make only 13 knots. It will thus be seen that the Italian boats have accomplished a great deal more on a very moderate displacement.

(2) *Reserve Buoyancy.*—The Italian boats, when running in light trim, have a reserve of buoyancy of 60 per cent. of their displacement. The French under-water craft of the *Aigrette* type have about 20 per cent. reserve buoyancy. The *Lake* type have 22 per cent., while the general run of the *Holland* boats have hardly 10 per cent. Even when water is admitted to the superstructure, the Italian boats retain a reserve of buoyancy of 30 per cent. It will thus be seen how seaworthy these vessels should be and what a large margin of safety they have against damage due to collision or any shock producing leaks.

(3) *Stability.*—The Italian boats stand quite alone in the point of considerable metacentric height when submerged. As has been said, the metacentric height in that condition is nearly 12 inches. In the large English boats of 300 tons displacement the metacentric height is only 9 inches, while in boats of the *Lake* type and *Protector* class it is only 7.2 inches. This gain in metacentric height adds very materially to the longitudinal stiffness of the Italian boats.

(4) *Submerged Navigation.*—The Italian boats can be submerged at once, and on an even keel, after a brief preparation in trimming from surface condition. The time required to adjust water ballast for this purpose is only five

minutes, which has not been accomplished by any other submersible or submarine up to date. The boats retain a positive buoyancy, and submergence is effected by means of two special propellers, which force the boats vertically downward. The various other submarine vessels in existence can be submerged only when under way if retaining a reserve of buoyancy. One would have to give these other vessels negative buoyancy if submergence on a level keel were desired. This would be a dangerous operation, as it would then be difficult to prevent the craft from sinking below the predetermined depth. The *Porpoise* sank in this manner and narrowly escaped destruction, and the *Octopus* did the same thing during her official acceptance trials, but, fortunately, the bottom was not so far away as in the case of the *Porpoise*. The Holland boats submerge when under way at an angle of 10 degrees to 12 degrees until the desired depth has been reached. This depth, however, can only be maintained by the exercise of great care and skill on the part of the operator at the horizontal rudder. Therefore, submerged navigation in shallow water at high speed with boats of the diving type is a very dangerous operation. The Italian boats run submerged with a change of longitudinal trim of not more than 1 degree to 2 degrees at the very most, and with a variance in vertical movement of less than 20 inches.



ITALIAN SUBMERSIBLE

(5) *Motive Power.*—The Italian boats are driven by three propellers. The middle screw serves for cruising purposes, while all three are in motion when running at full speed. For submerged navigation the side screws only are operated. When running at cruising speed the central screw alone is used at full power. The motors can thus be used at all times to the best advantage. By a simple adjustment of the mag-

netic fields the electric motors used for submerged navigation can be so cut down in the number of their revolutions that they can be operated efficiently at the modest rate of 25 per cent. of their high speed, and that without diminishing the tension. Switches for the batteries are thus done away with. The accumulators themselves are small and handy. The weight of one unit amounts to only about 250 pounds. Their removal in case of accident is, therefore, much facilitated. With the heavy cells carried by the Lake and Holland boats, this operation is a most difficult one, because each cell weighs not less than 1,200 pounds. The battery is hermetically sealed, and the gases developed are expelled outboard by special means. Hence the danger of an explosion by reason of these gases—which has been proved fatally great in some other submarines—is accordingly greatly reduced in the case of the Italian boats. The explosive motors are driven by benzine. Up to the present time this is the only fuel permitting the construction of light motors of sufficient power to produce high speed. The manner of stowing the benzine and arranging its feed to the motors are such that no annoying features have manifested themselves at any time since these vessels were put in active service.

(6) *Division by Means of Bulkheads.*—The interior of the Italian boats is divided into eight separate watertight compartments. In this feature the Italian boats are distinctly unique. This divisioning makes it possible to seal hermetically and divide the engine rooms from the remaining divisions, and, by so doing, preventing the heat and any possible gases from the engines spreading into the other parts of the boats when submerged. Submergence is not delayed until the engine space has cooled down. It is simply closed at once and allowed to take care of itself until the boats are ready to return to the surface and to resume there propulsion under engines. Furthermore, the safety of the craft is considerably augmented by this system of subdividing. The serious accidents that befell the French and English submarines showed plainly the need of subdividing by means of

watertight bulkheads. During the last Italian maneuvers the submarine boat *Squalo* continued to run submerged, despite the fact that she carried more than a ton of water in her engine room, which had gained admission there by reason of a defective valve of the water jacket of the motors. The American submarine *Shark* lost her reserve buoyancy through a leak in her engine exhaust valve, and very narrowly escaped going to the bottom in 1904. In the case of the *Shark*, only a few pounds of water thus leaked into the vessel, yet it was enough to imperil her.

(7) *Torpedo-Firing Tubes.*—The Italian boats carry two bow torpedo tubes with their forward ends so formed that they offer but very little resistance to the water. These torpedo tubes, which are capable of carrying 18-inch torpedoes, are so placed that they lie somewhat back and below the stem, so that they are safeguarded in case of bow-on collision.

(8) *Hull.*—The hulls of the Italian boats are not formed with the customary circular cross-section with a superstructure. They are built upon a patented system, and in form are quite like the ordinary torpedo boat. Apart from giving the vessels easy lines for surface speed, this particular construction admits of a very convenient arrangement of the machinery. The extreme bow and stern ends of the vessels are high enough inside for a man to stand upright. Because of their special form it is possible to mount in the Italian boats more powerful motors, larger accumulators and bigger pumps than are permissible upon the same displacement in submarine vessels having the usual spindle form of main hull. Even though the Italian boats have not the circular cross-section recognized as being that best capable of resisting high compression, still they are able to withstand safely a submergence of 150 feet, if such be required.

(9) *Sighting Instrument.*—The Italian boats are equipped with two sighting instruments for submerged navigation. These instruments are of the Russo-Laurenti type, and possess a field of vision of 50 degrees. The portion extending

above the surface has a diameter of about 3.5 inches. The instrument is so designed that the eye piece gives a large image, and does not require the observer to keep his eye constantly fixed thereon. In this way eye fatigue is avoided and continual observation can be had without any of the tiring stress common to the general run of these instruments. The instruments are so arranged that they give normal vision and magnified vision, the latter being designed to enable the observer to distinguish distant objects and to read correctly visual signals.—"The Engineer."

H. M. S. *SWIFT.*

A vessel which will, it is claimed, prove when completed to be the fastest in the world was successfully launched from the shipbuilding yard of Cammell Laird & Co., Limited, Birkenhead, December 7, in the presence of a large concourse of people. The *Swift*, the name by which the vessel will be known, is being built for the British Admiralty to meet the requirements of a special type of ocean-going torpedo-boat destroyer, and is of considerably larger dimensions and higher speed than any former vessel of the destroyer class. She is designed for a speed of 36 knots per hour as against the 33 knots of the *Tribal* class of sea-going destroyers.

Her principal dimensions are: Length between perpendiculars, 345 feet; breadth, 34 feet; depth, 20 feet 4 inches; with a displacement at her mean load draught of about 1,800 tons. Her armament consists of four 4-inch breech-loading guns, two on the forecastle and two on the upper deck, and two 18-inch torpedo tubes on the upper deck. She will be propelled by quadruple turbine machinery of the Parsons type manufactured by Cammell Laird & Co., Limited, at their Birkenhead works. As in the new large Cunard vessels, the turbines will drive four shafts, there being one propeller on each shaft. The turbines are placed in two distinct engine rooms in order to minimize the capacity of any one water-

tight compartment, and several novelties have, we are informed, been introduced in order to accommodate machinery of the large power required in the comparatively small space at disposal.

There is an installation of twelve boilers of the Express straight-tube type, these being arranged for the burning of oil fuel. The boilers have been built by the firm at their Beaufort-road works.

THE PROGRESS OF THE TORPEDO.

As vital national issues are dependent upon munitions of war, it is universally agreed that their efficiency should not in the slightest degree be weakened by unsatisfactory details, least of all on the score of expense. This view further requires that every unit constituting the complete implement of war must be of the most approved form. The fastest cruiser with anything short of the most powerful guns possible within the limits of weight permitted by general considerations of design would not be satisfactory. A battleship well armored, with the best of propelling machinery, and with the most reliable of guns, would be a source of weakness to a fleet if her gun mountings were unsound. Such points are often forgotten in elaborate statistical comparisons of the fleets of different Powers, and yet they are almost as important to fighting efficiency as the skill and experience of the personnel. In the measuring of relative efficiency, the only substitutes for the test of actual warfare are the maneuvers, which are more extensive in the British than in other services. A comparative study of contemporaneous progress in the mechanical sciences associated with peace and war industries further enables one to appraise with moderate accuracy the official attitude towards appliances which give reliable promise of increasing the efficiency of weapons of warfare. The evidences afforded by these two standards of measuring progress are reassuring so far as the British Navy is concerned. In recent years the tendency has been distinctly progressive.

The existing exceptions are, as a consequence, the more surprising, and call for the keener criticism.

One of the most important instances where there has not been a ready response to successful unofficial effort towards improving war munitions is in the case of the torpedo. Recently we have placed on record the splendid results achieved by torpedo-boat destroyers, which realized speeds of from 33 to 35 knots, and now we have in a paper read before the Liverpool Engineering Society by Mr. E. C. Given convincing proof of the success of the submarine or submersible boat. All is thus well with the vessels which are to use the torpedo as a weapon of war. But when measuring the significance of the efficiency of these surface and submersible torpedo-firing boats, it is imperative that the efficiency of the torpedo itself should be considered. If the most effective weapon is not used, the best cannot be got from the boats. It is idle to increase the expenditure of a surface boat from £70,000 to £120,000, to get 34 knots instead of 30 knots, and at the same time accept a torpedo which has a speed of only 24 knots at 3,000 yards range, when there is available a weapon of 32 knots speed at the same range, and particularly when other Governments are adopting the new instrument. Modern naval tactics favor long range, and the torpedo which has a speed of 28 knots at 4,000 yards range will be immensely superior to one of from 18 to 20 knots at such range. The advantage is correspondingly greater at shorter range. Indeed, the formerly approved practice of fitting bow tubes to warships had to be discontinued because the speed of the torpedo-boat, and even the cruiser, was approximately so nearly to that of the torpedo itself. When, in 1886, the 125-foot torpedo boats could overrun the torpedo then available, the Mark IV Fiume torpedo was introduced, and gave the necessary improvement in speed, but only for the short range of 600 yards. Some years ago the same difficulty of relative speed again arose, and the bow tube was abolished. The best torpedo in the Navy at 1,000 yards range has a speed of only 35 knots, and at 1,500 yards range 30 knots. Destroyers

of 33 to 35 knots would thus overtake the torpedo they had fired ahead in less than two minutes. Thus with low-speed torpedoes any attempt to fire ahead would be attended by serious danger.

Now torpedoes are available which have a speed of 43 knots at 1,000 yards, and of 40 knots at 1,500 yards; so that, if these were adopted, we could return with greater safety to the bow tube, which has great advantages. A destroyer approaching the enemy bow on, alike in open sea or restricted waters, presents a much smaller target, can fire the torpedo more easily, and, reversing engines, can escape backwards more quickly. Thus it used to be a condition of the contract, in some foreign navies—if not also in the British service—that a given astern speed should be realized on trial. The contingency that the charged point of a torpedo in a bow tube, being above water, was likely to be struck by a projectile, scarcely holds, since above-water tubes are fitted elsewhere in the latest ships.

The splendid results achieved by the latest torpedoes, giving an increase in speed of about 10 nautical miles per hour at all ranges, has been achieved by the application of air heaters. It is now some years since the world was startled with rumors from America of the extraordinary results achieved by the Bliss-Leavitt apparatus for heating the air of torpedoes, and from that time the firm of Whitehead & Co. have devoted considerable attention to the investigation of this subject. Having taken over the patents of Sir W. G. Armstrong, Whitworth & Co. in connection with heating devices, they have succeeded in producing a heater considerably more efficient than was accredited by rumor to the Bliss-Leavitt. The heater consists of a small steel chamber between the air vessel and the engine of the torpedo, in which a certain amount of liquid fuel is burnt in conjunction with the air passing to the engine, resulting in a gain in power of 100 per cent. as compared with the same engine and air vessel when run cold. It is, however, in the extreme simplicity and safety of the Whitehead hot-air torpedo that

its chief claim to superiority lies. The whole apparatus takes up only about 3 inches of the torpedo's length, and weighs about 12 pounds. Details of construction are, of course, only known to the makers; but they are such that no difficulty is experienced in handling the torpedo by any man acquainted with this weapon. In order to show clearly the advantages which have been obtained by thus heating the air, the following table gives the speeds at various ranges of the latest Whitehead torpedo when run cold and hot; and, in this connection, it may not be out of place to remark that the latest Woolwich torpedo does not equal the Whitehead as regards speed at any range:

TABLE SHOWING SPEEDS OBTAINED BY THE LATEST WHITEHEAD 18-INCH TORPEDO.

	With cold air.	With hot air.
At 1,000 yards, knots	35	43
1,500 yards, knots	30	40
2,000 yards, knots	$28\frac{1}{2}$	38
3,000 yards, knots	23 to 24	32
4,000 yards, knots	18 to 20	28

As we have already said, foreign countries are showing keen interest, and are acquiring torpedoes fitted with this heater; and at the present time the United States Government are obtaining these weapons from the Whitehead Company at Weymouth, whilst the Whitehead Works at Fiume are extremely busy with orders from European Governments and some States of South America. At the present time, we understand, the British Admiralty has, so far, not followed the example of foreign countries. It is impossible for the Admiralty to long delay equipping the Fleet with the torpedoes so markedly superior to those of the Government's own construction, in view of the activity displayed by other countries in providing themselves with complete equipments of this weapon.

The importance of having the very fastest torpedoes available is great, not only on the grounds that the torpedo should, at least, be faster than the torpedo craft, but also because the errors which are of necessity present in practice with these

weapons are very much reduced as the speed increases; and the possibility becomes more remote of the enemy avoiding a torpedo when its track discloses its progress. As the result of a large number of runs with the Whitehead hot-air torpedo at Portland, it was clearly shown that for steadiness of running, both for speed and direction, the hot-air torpedo is superior to the same torpedo when running cold; this superiority being more marked in cold weather, as after the water temperature has dropped to about 40 degrees F. it is impossible to run the ordinary cold-air torpedo. Thus every consideration establishes the great importance of the adoption of the new weapon, and until this is done the best cannot possibly be realized from the improvements achieved with our torpedo craft.

The unceasing work done by the naval architect and marine engineer to improve the craft, while the torpedo authorities seem to be standing still, can be easily demonstrated. One instance must suffice here. Our new destroyers, of 790 tons' displacement, steam 34 knots for 11.36 tons of oil fuel per hour, and continue thus on official trial for six hours, while ten years ago the boats of limited capacity and radius of action, because of only 360 tons' displacement, required 8 tons per hour for 30 knots, and even then could keep this up for only three or four hours. The engine power has had to be trebled, and yet the weight of fuel used is increased only about 40 per cent.

The paper read by Mr. Given indicates that corresponding progress is being made with submersible boats. He deals with the vessels built for all Powers. In the British boats, which have increased in displacement from 120 to 500 tons, the surface speed has been augmented to the extent of about 75 per cent.—from 8½ to 15 knots—while the submerged speed has increased 30 per cent.—from 7 to 9 knots. It will be realized that great difficulties are associated with increase of speed, especially submerged. The power then utilized is electric, and the current must be stored in batteries. Thus, while the oil engines used for propulsion, according to Mr.

Given, weigh about 56 pounds per brake horsepower, the weight of the electric mechanism is 235 pounds per electric horsepower. Strategists are not, however, agreed as to whether high speed, when submerged, is necessary. Mr. Given says: "The surface speed is the strategic speed, enabling the vessel to quickly reach or leave the fighting zone; whereas the submerged or tactical speed is of less importance (except for attacking moving vessels), as when submerged they are unseen; and it is thought that the only means of attacking a submarine is with a spar-torpedo, and this is extremely difficult to carry out, as the submarine can dive or maneuver out of reach if the water be deep enough." With increased length there is a possibility of increased surface speed, but the fine ends of the ordinary surface boat cannot be approximated.

The proportion of length to beam in submersibles has undergone a great change. The earlier British boats had a length of about five times the beam, and the later ones of about ten times the beam. The increased length tells against the diving and maneuvering, especially in shallow and confined waters, so that the problem of speed is one of great difficulty, particularly if the success hitherto achieved—notably with British vessels—in connection with maneuvering and quick diving is to be continued. No doubt the speeds will increase, and we shall at an early period have submarine boats corresponding in speed to the battleships, with equal radius of action and good sea-going qualities. That being so, there is the greater need for an active policy at the Admiralty in connection with torpedoes, without which the submarine or surface torpedo boats are practically useless. We have no doubt that Parliamentary pressure would result in a more courageous policy in this matter. We cannot believe that the question is one of economy. No doubt the replacing of the existing torpedoes of deficient range by the latest instruments would involve a considerable sum, but when it is considered that the efficiency of vessels, costing millions of

pounds, is greatly lessened by the absence of the best torpedo, only "economists at all costs" would oppose any proposal for adopting the new torpedo.—"Engineering."

VANADIUM STEEL IN THE UNITED STATES.

Several interesting experiments and developments in the manufacture and use of vanadium steel have been made in the United States. The American Vanadium Company has developed five grades of steel, the character of which is shown in the accompanying Table No. 1. These are kept as free as possible from sulphur and phosphorus. Sulphur may be as high as 0.035 per cent. With phosphorus up to 0.02 per cent., the silicon may be as high as 0.10 per cent. in the first three and 0.15 per cent. in the fourth grade. With phosphorus as high as 0.03 per cent. the silicon should not exceed 0.05 to 0.06 per cent. in the first three grades or 0.10 per cent. in the fourth.

TABLE 1.

	No. 1.	No. 2	No. 3.	No. 4.	No. 5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Carbon	0.25 to 0.30	0.20	0.20	0.45 to 0.55	0.12 to 0.15
Vanadium	0.16 to 0.18	0.12	0.16	0.18	0.12
Manganese	0.40 to 0.50	0.30 to 0.40	0.40	0.80 to 1.00	0.20
Chromium	1.00	0.50	0.80	1.25	0.30

With steel No. 1 three methods of heat treatment were employed: First, annealing at 800 degrees centigrade for one or two hours, and then cooling in air or ashes according to the character of the work; secondly, quenching from 900 degrees centigrade in lard or fish oil and then annealing for from one and a half to two hours; thirdly, quenching from 950 degrees in lard oil and letting down at 360 degrees for 15 to 30 minutes in a lead bath and then cooling in air. This grade of steel treated by the first process is suitable for light axles, connecting and coupling rods, driving axles and piston rods. If treated by the second process it is employed for crank shafts, crank pins, transmission parts and gear wheels. Steel No. 2 requires no special heat treatment and is intended for

axles, rods and parts in which strength to resist torsion is of importance; it is also used for large machine bolts. Steel No. 3, which also requires no special heat treatment, is suitable for axles, rods and bolts. Steel No. 4 may be subjected to the following heat treatment: First, annealing at 800 degrees centigrade for one hour and cooling slowly down to 600 degrees, care being taken not to chill the steel by too rapid reduction of temperature. With this treatment the steel is suitable for solid-center, railway-carriage and wagon wheels, crank pins and gun barrels. Secondly, quenching in oil from 900 degrees centigrade and drawing back at 450 degrees in a lead bath, then cooling in air. With this treatment the steel is adapted to springs for locomotives, automobiles and carriages. Steel No. 5 is subjected to the ordinary case-hardening process, and is used for ordinary machine and engine parts. The results of tests of ordinary "carbon" steel, nickel steel and vanadium steels of a grade adapted for automobile work resulted as in Table No. 2.

TABLE 2.—TESTS OF STEELS.

....	Axle-steel.	Nickel axle steel.	Vanadium steel No. 1 with heat treatment.		
			No. 1.	No. 2.	No. 3.
Yield point, lb. per sq. in.	41,300	49,270	63,570	110,100	224,000
Ult. strength, lb. per sq. in.	65,840	87,360	90,080	127,800	232,750
Ratio, per cent	62	56	66	87	96
Elongation in 2 in., per cent	42	34	33	20	11
Contraction of area, per cent	61	58	61	58	39
Torsional twists	2.6	3.2	4.2	2.5	1.8
Alternating bends	10	12	18	10	6
Pendulum impact, ft-lb.	12.3	14	16½	12	6
Alternating impact, number of stresses	960	800	2,700	1,850	800
Falling weight on notched bar, number of blows	25	35	69	76	...
Rotary vibrations, number of revolutions	6,200	10,000	67,500	...	...

Cast-steel frames for locomotives have been made with vanadium steel by the Union Steel Castings Company. Five frames were made from one heat for four, six and eight-

coupled engines, the weight of each frame being from 4,400 pounds to 5,600 pounds. The steel poured quietly and the frames were finished satisfactorily. It was stated that this heat was the best ever made, and it is considered that the use of vanadium will result in producing castings more nearly perfect and solid than those of ordinary carbon steel. It is not detrimental to the quality of the steel with regard to resistance to static strains, while the vanadium steel is decidedly superior to ordinary steel when dynamic stresses have to be resisted. The company has issued a statement relative to its experience. From this we abstract the following:

"We form test bars of 8 inches with ½ inch connection. To detach one of these test bars from an ordinary steel frame requires from six to twelve blows with a 10-pound sledge. Test bars on a frame made of vanadium steel required from 100 to 150 blows by the same man with the same sized sledge. The fracture of vanadium steel is closer and presents a much tougher appearance than ordinary steel. Two samples were tested in a vibratory machine deflecting a bar 7 inches in length and ⅝ inch diameter, ⅛ inch on each side of the center, making ¼ inch deflection. The average number of vibrations required to break a bar of ordinary steel was 4,206, while the average number of vibrations required to break a bar of vanadium steel was 12,776.

"We also bent a sample of ordinary steel and one of vanadium steel to an angle of 90 degrees, and reversed them by bending in the opposite direction to an angle of 90 degrees. The ordinary steel bent three and one-half times before breaking, and the vanadium bent four and one-half times. In bending a ½-inch by 1-inch test bar of vanadium steel on a single bend under a hammer, it was bent flat on itself without fracturing or shearing. A similar sample of ordinary steel of same analysis, except as to vanadium, also bent flat on itself but sheared slightly.

"If the carbon were increased in the ordinary steel so as to give a tensile strength of 77,800 pounds, it would give almost, but not quite, as good results in elongation and reduction as

vanadium steel. The elastic limit, however, would probably fall about 5,000 pounds below that obtained with the vanadium steel. In view of the fact that the bending bars of vanadium steel were over 77,000 pounds in tensile strength, while those of ordinary steel were slightly over 68,000 pounds in tensile strength, we come to the conclusion that the results obtained indicate that the vanadium steel is very much tougher than the ordinary steel. If ordinary carbon steel of 77,000 pounds tensile strength or over had been used in making the bending and vibratory tests, the results would have been very much inferior to those obtained from the lower carbon steel."

In planning the vanadium-steel frames, the tool was made to take the same cut as with ordinary cast-steel frames. The metal was found to be harder and tougher and more difficult to cut, but not sufficiently to affect the time of machining. The chips of vanadium steel were much larger, tougher and more regular than those from ordinary steel.

In a welding test, two pieces were welded together and then planed to a section ½-inch by 1-inch, for the testing machine. The fracture indicated that the weld was not quite perfect on one side, and it left a slight fin. The bar did not break, however, until a pull of 72,460 pounds had been reached.—"The Engineer."

MECHANICAL POINTS IN CONNECTION WITH STEAM TURBINES.

The feeling of untrustworthiness which for so long was the predominant note in connection with turbine work dies hard, and is still very rampant in many quarters. A veil of secrecy necessarily accompanies the development of such a revolutionary prime mover, and consequently many of the difficulties which occur gain an undue importance in the eyes of those not intimately acquainted with turbine construction. Apart entirely from the question of economical fuel consumption, the success of a prime mover depends on its reliability for continuity of operation. It is natural to expect that mechan-

ical troubles not hitherto experienced should be met with, but it is surprising what a large proportion of the troubles which have been experienced and have contributed to the creation of this feeling are due to causes which are not inherently embodied in the turbine principle. Had the same details and methods been used on reciprocating engines, trouble would have certainly followed. These remarks are not confined to any one type of turbine, or to those constructed in this country. Engineers in all parts of the world are actively engaged in turbine development, and it is very striking how universal the custom is to treat the accessory details as requiring special and novel designs.

In contradiction to this view it may be taken that the details will ultimately become simplified into similar designs to those which have proved themselves on reciprocating engines. In this article some of these points will be considered, and to avoid repetition commencement will be made at the steam inlet, and the other parts will be taken in sequence through the machine.

Steam Pipe.—With some of the methods of connection adopted this has proved a fruitful source of cylinder distortion. The longitudinal expansion of the cylinder must be provided for, in addition to that of the steam pipe. The length of pipe connecting to the cylinder should be a bend of sufficient elasticity to take up the expansion without putting any undue stress on the cylinder. The end remote from the cylinder must be securely anchored, so that the rack and strain of a long length of piping is isolated from the cylinder. Anchoring the pipe also prevents vibration being transmitted to the steam range. The high-period vibration of a turbine, although of small amplitude, often coincides with the natural period of vibration of the piping, and causes the latter to dance violently. In support of the contention at the commencement, it may be remarked, in passing, that this is precisely what is necessary in connection with reciprocating engines; yet almost every one connected with turbine work has experienced much trouble from neglect of this simple precaution, and it

will be noticed that a similar parallel exists in many other cases.

Cylinder.—The usual trouble experienced here is distortion, which may be caused by temperature or external forces. If the steam and exhaust connections are properly made, and the chest containing the governor valve, &c., suitably supported when placed on the side, it resolves itself into a question of design. The horizontal joint is an addition to the problem, but in many respects it is akin to that which has to be faced with large steam-engine cylinders. In one respect it has the advantage, for it has no rapid and continuous changes in temperature to withstand. After it is once heated up it remains approximately the temperature of the steam with which it is in contact right through, from inlet to exhaust.

Ribs and branches should be avoided wherever possible, and the barrel retained as a plain cylinder. After rough machining and before finishing, the castings should be annealed at a temperature of about 1,000 degrees F., to relieve all casting stresses. This is especially important when highly superheated steam is used. Although a turbine can be started up cold without the risks attendant on similar treatment of a reciprocating engine, it is obviously inadvisable to do so unless under urgent necessity. The more gradual and thorough the heating-up process, the less likelihood of distortion, as the flanges and facings will have time to warm up in addition to the thinner barrel metal. The methods of supporting and securing the cylinder for reaction turbines must be carefully designed to prevent hogging. Many a blade strip has occurred through neglect to ensure free longitudinal expansion. The distribution of the non-conducting material used also demands careful consideration, and the horizontal flanges must be well covered. The covering over the flanges must be made removable to allow of lifting the top half of the cylinder, and neglect to replace it before starting up has led to disaster. A moment's reflection will make the reason apparent.

The Revolving Element.—The objects to be attained are rigidity and balance. So long as the deflection does not

exceed a certain amount, and accurate workmanship with homogeneity of metal are ensured, rigidity and balance can readily be obtained. The parts can be either forced or shrunk together and secured in various ways. That parts of spindles have worked loose in service emphasizes the necessity of special attention being given to providing positive locking arrangements. A good method of construction is that of forcing on with only sufficient forcing allowance to insure a a good fit, in which case a key must be provided to transmit the turning moment. This enables the various parts to be finished and balanced before assembly, which materially facilitates the balancing of the complete spindle, there being no distortion from the forcing.

Couplings.—Most of these troubles have been due to defects in lining up, or insufficient contact surface causing wear and tear, with consequent heating and vibration. It is questionable with some designs how much flexibility in the horizontal direction actually exists when the plant is running on load. The generator shaft should have ample bearing collars to restrict the longitudinal movement, so that driving is the only duty which the coupling has to perform.

Main Bearings.—Contrary to natural expectations, little trouble has been experienced here. The troubles which have occurred have been mainly due to defective lubrication. Bearings of the sleeve type are desirable for speeds of 2,000 R.P.M. and upwards, but below 2,000 R.P.M. solid bearings of cast iron, babbitted, are quite satisfactory. The seat should be spherical, and the shell of ample strength. The two halves of the bearing must be securely bolted together to prevent any springing in the overhung parts. Although water cooling has been provided on very large bearings, it is better to dispense with water cooling, and to supply a sufficient quantity of oil to carry off the heat. The water connections on spherical-seated bearings are liable to leak and give trouble with the oil. The lubrication of bearings will be considered under "Oil Service."

Thrust Bearings.—Although the primary purpose of the

thrust bearing is to regulate the relative positions of spindle and cylinder, it can, of course, take some load. The single-flow reaction turbine is designed to be balanced and free from end thrust, but the possibilities of an end thrust do exist. When starting up a new machine, the direction and amount of the thrust must be determined, and a balance obtained by adjusting the blading. Unless this end thrust is carefully balanced, the thrust bearing will wear, with consequent trouble at the dummies. The importance of correct balance and thrust adjustment is so great that some further provision than that commonly provided for the purpose would prove a great advantage, especially for repair and overhauling on site.

Oil Service.—The conditions to be met are continuity of supply and efficient filtering and cooling arrangements. Practically the universal system is to supply oil under pressure either direct from the pump or from an overhead tank. The advantage of the tank is that it can act as a reserve in case of pump failure, and also be used to flood the bearings before starting up. For moderate sized units the self-contained system, *i.e.*, turbine driving its own pump, is undoubtedly the best, but for extensive stations of large units the independent central system has many advantages. For self-contained sets a small hand pump for flooding the bearings before starting up is a cheap and desirable addition. A small horizontal steam pump is sometimes used for this purpose, in which case it also serves as a standby in case of need. The problem of bearing lubrication on the turbine differs in some important respects from that on a double-acting reciprocating engine. There is no reversal of pressure on the journal, and consequently no knock to be absorbed. In addition to lubricating the bearings the oil has to carry off a much greater quantity of heat than on an engine, for, besides the heat generated in the bearing, heat is conducted along the shaft from those parts in contact with the steam. The quantity of oil required to be passed through a similar bearing per unit of time is much greater than in reciprocating-engine

work, and provision must be made for a continuous flow through the bearing. Except to ensure the bearings being flooded with oil there is no need for pressure, as the oil is drawn between the journal and bearing in the same manner as with the oil bath in the experiments carried out by Mr. Beauchamp Tower for the Research Committee of the Institution of Mechanical Engineers.

Although the velocities and pressures used in those experiments are not such as are common in turbine work, still much can be learned by a study of the distribution of pressure in the bearing and the results of the various methods used for feeding in the oil. One highly-successful method for solid bearings is as follows: The top half of the bearing only touches the journal by a narrow strip along the vertical center line and around the ends of the bearing, leaving a pocket on each side. The strip along the top is to prevent the shaft from rising, and the strips at the ends form the pockets which are used to provide an oil bath. The lower half of the bearing is relieved at the horizontal center line for a distance corresponding to the pockets in the top half to prevent the journal being nipped. This also serves to feed in the oil. It extends for a small part of the circumference and is tapered off to the bore of the bearing. The oil inlet is in the top half of the bearing on the downward side considering the direction of rotation of the shaft. The oil is carried round by the shaft and discharged into the pocket on the other side. Grooves are cut through the strips at the ends of this pocket to allow a proportion of the oil to escape and insure a sufficient circulation. Of course, a quantity of oil escapes all round the bearing, but it is usually necessary to add some grooves in addition. No grooves whatever should be cut in the bottom half of the bearing, as they only allow the oil to escape and materially reduce the load which could otherwise be safely carried. A consideration of the distribution of oil pressures, as recorded in the tests previously mentioned, will make the reason obvious.

The oil leakage, where the shafts pass through the bearing

pedestals, has proved a source of complaint. The thin brass scraper rings, which have been largely used to prevent the oil creeping along the shaft, are inadequate. The positive oil thrower, universally used on enclosed splash and forced-lubrication engines, however, usually meets the case, although the fan action of the generator is much greater with turbine-driven sets. This produces a region of low pressure around the pedestal, where the shaft passes out, and induces a current of air to pass through the pedestal so as to suck out the oil. In cases where clearances have been cut fine this point has assumed great importance, owing to oil getting into the generator windings. It is especially difficult to prevent leakage when, in addition to the natural fan action of the generator, devices are included in the generator design to induce a current of air for ventilating purposes. In such cases the only absolute security is to isolate the end of the pedestal from the suction effect. Except for very small pipes, flanges should be used with metal-joint rings. Any other packing material is affected by the oil, with consequent leakage. Much of the oil piping is exposed to view, and any slight weeping which would not be of importance on an enclosed engine is highly objectionable for the sake of appearance. When the turbine drives the oil pump there is a large choice of the designs which can be employed. There is the ordinary plunger pump with valves, the valveless plunger pump universally used on forced-lubrication engines and several designs of rotary pumps.

Each type claims some advantages, but owing to the great success of the valveless pump and the confidence inspired by its wide and extended service, it will naturally take a large share of the turbine work. In view of the success which has attended the simple oil-straining system adopted on forced-lubrication engines, the methods used with many turbine installations are very surprising. In some cases a small box, containing several screens of wire gauze or calico, is connected with the delivery side of the pump, and about 10 per cent. of the discharge is by-passed through the strainer. It

is claimed that the filtration of this volume is sufficient to keep the whole body of oil in a satisfactory condition. In other designs the oil flows over perforated trays, from the under side of which hang bags made of calico or similar material. The oil, being hot and thin, percolates through and falls into a tank underneath. The upkeep and attention required to keep these bags in a satisfactory condition must be a considerable item. The objection raised to putting the strainer on the pump suction, which is commonly done with forced-lubrication engines, is that, should the strainer become clogged, the oil is cut off. One method of avoiding this is to arrange the strainers so that the oil gravitates through them, and in the event of them becoming clogged the oil overflows into the suction chamber. As, however, it is usually impossible to arrange much gravity head, the strainer surface required becomes much greater than where the head due to the suction pump is utilized. That some strainer is absolutely necessary in commercial service experience has amply proved, and if accessibility is provided there is no reason why the system, which has proved successful with the reciprocating engine, should not do equally well on the turbine.

The oil-cooling problem is a very important one, and is much more difficult than is commonly imagined. Temperatures of 120 degrees to 130 degrees F. for the oil leaving the bearing are not uncommon. Some engineers advocate 150 degrees to 160 degrees F. as being quite safe with suitable oil. The oil to the bearing is usually some 15 degrees to 20 degrees F. less than that at which it leaves the bearing. All pipe joints must be metal to metal and positively locked to prevent leakage, so that designs, on the ordinary condenser lines, with packed glands, are out of the question. Copper coils immersed in a tank of oil, with the cooling water passing through them, are notoriously inefficient, owing to the cooled oil adhering to the outside of the tubes and acting like a blanket. Pumping the oil through the coil with the water outside is a considerable improvement. To obtain the maximum cooling capacity per square foot of tube surface, the

counter-flow system should be embodied in the design, and the tank so arranged that the fluid outside the coils is obliged to flow along their whole length and be brought intimately into contact with them. Provision must be made for examination and cleaning, and the more readily this can be done the greater the likelihood of the cooler being kept in an efficient condition. The coils should be well clamped and supported to prevent vibration. Owing to the persistency with which oil permeates any porous metal, special attention must be given to all castings which will contain oil, whether under pressure or otherwise. They should be so designed that no chaplets need be used, and all liability to porous metal must be avoided. Testing under water pressure will locate any leaky spots and possibly save much trouble and expense later. In some cases oil indicators are fitted on each bearing. Except under special circumstances, this is quite unnecessary, and a pressure gauge connected to a suitable point in the system is all that is required. We consider that the multiplication of safety devices, unless absolutely necessary, does much harm, owing to the distrust they inspire by the suggestion of possible failure.

Governing.—The system of operating the governor valve by means of steam or other working fluid in a relay cylinder, or electrically, has been very popular in turbine work. In view of the great success attending the direct-operated governor valve used on high-speed engines, there can be no doubt that this method, which is much simpler, can be equally successful on turbines governed by throttling, and requiring up to 8-inch or 10-inch diameter valves.

The oscillating gear in conjunction with a steam relay cylinder, commonly used on one type of turbine, certainly overcomes the friction of rest; but, if this is of vital importance, why have not the engine builders been driven to the same solution of the difficulty?

There is no difference in steam consumption, for the results with the oscillating gear follow the straight-line law characteristic of throttle governing with a direct-connected

valve. Supporters of the oscillating gear contend that with a turbine the friction of rest has a greater effect in producing "stickiness," owing to the even turning moment of a turbine, whereas the comparatively uneven turning moment of a reciprocating engine tends to keep the governor and gear continually on the move, although so slightly as to be practically not apparent. However, in order to obtain satisfactory operation when running in parallel, some turbine makers have found it necessary to reduce the travel to the least possible amount and to increase the periodicity of the oscillations to about 250 per minute, thus reducing the valve beat to a small vibration, so as to tone out the impulses given to the rotating part by the gusts of steam. The trouble probably arose with sets where the rotating parts were unusually light. In view of these facts, failure from this point need not be anticipated. That indifferent governing has been experienced with direct-operated valves may probably be accounted for by other reasons. With the oscillating gear the valve seats itself at each beat, when on light loads, so that both seats must be the same diameter, involving a loose seat ring. If uneven diameters are used "hunting" will result at light loads. An air dashpot is commonly arranged on the valve spindle; but, as the travel is small when the valve is seating, the dashpot is of little service when most needed.

To overcome this difficulty an arrangement of joggle links is used by some builders to vary the lift of the valve with the load so that the lift is increased as the load decreases. In any case, however, the loose seat ring is a weak point. Also the beating soon wears a facing of considerable width on the seats and causes leakage should the valve be required to shut the steam right off. This reason has contributed to the undue importance given to the safety governor valve. Engine builders long since found out the impossibility of making and keeping a double-seated valve tight with anything wider than a knife-edge contact. With a direct-connected valve of the design commonly known as the Belliss type the seats never come into contact except when the governor flies to the

extreme outer position, so that the seats keep in good condition. In that design the seats can be made of slightly different diameters, so that a loose seat ring is not required. The shape of the valve and seating also lends itself to a successful design for expansion, especially under superheated-steam conditions. The valve should be carried on a small-diameter spindle passing through a long bush to prevent it being much out of balance and to obtain steam tightness with a minimum of friction. No adjustable stuffing box should be used, as it may be screwed up sufficiently to nip the spindle. In designing the connections care should be taken that no bending moment is put on the valve spindle, as, owing to its small diameter, it is easily distorted slightly and then stickiness results. The valve spindle is the only delicate point with the direct-connected governor, but that it can be made absolutely reliable is amply demonstrated by the thousands of sets in successful operation. The connection between valve and governor should be direct, rigid, contain few joints, and be as light as possible to reduce inertia. For this reason rods and rocking shafts of large-diameter tubing should be used to obtain rigidity with the miuimum of weight. The governor is a detail showing great divergence in design. The elaborate designs, built up of many parts, often defeat the very objects for which they are produced. Here, again, engine builders have evolved by experience simple designs, which are not only much cheaper to make, but wear far longer and give better results under service conditions than more elaborate kinds. Summed up, the engine builders' experience amounts to:—(*a*) Few parts, designed to facilitate accurate workmanship; (*b*) few joints, with ample bearing surfaces; (*c*) plain pins, instead of knife edges; and (*d*) forced lubrication throughout.

It has been found advantageous, with a direct-connected valve, to provide a more powerful governor than at first consideration would seem necessary. The cost is very small, as the speed can be kept high. Although the power may never be required, it places all fear of possible trouble from friction

out of the question. Compared with a steam relay cylinder and oscillating gear, the direct-connected valve possesses far less possibilities of failure, is adjusted much more easily and requires less attention in operation. The bearings requiring hand lubrication are very few, while their movement is extremely small.

With a relay cylinder actuated by a fluid, operation depends on the pump. The objection to all relay systems is their tendency to lag or overrun, and also to stick unless kept continually reciprocating. The governor is usually fixed on a reduced speed shaft driven by the main shaft through a worm and wheel. The main shaft has adjustable bearings, but the second shaft is often not made adjustable. Consequently the worm and wheel are not correctly lined up at the pitch lines, with resultant excessive wear and tear. With oscillating governor gear the worm-wheel shaft is horizontal, and drives the gear by an eccentric or cam on this shaft. The governor is fixed on another vertical shaft driven by bevel wheels or skew gearing from the horizontal shaft. With a direct-operating governor gear this second shaft and gear wheels can be dispensed with, and the possibility of trouble with this set of gear wheels will be avoided. When a reduced speed shaft is required to drive a plunger or rotary oil pump there may be some advantages by fixing the governor on this shaft, whether it be horizontal or vertical; but probably with a direct-operating gear it will ultimately be fixed on the main shaft. Naturally the desire arises to develop some form of rotary pump suitable for fixing on the main shaft, and so avoid all gearing. This would slightly increase the overall length, but the positive drive and elimination of all gearing would more than compensate for a slight increase in length. The safety governor is mainly a concession to the fear of a possibility which should be practically unknown under service conditions. The consequences of a turbine running away would, of course, be very serious, but there should be no reason to anticipate the failure of the main governor more often than on reciprocating engine sets, and far too much emphasis has

been given to this point. Its services are required only as a last means to prevent disaster, and every care should be taken to insure successful operation under all possible conditions which may arise. For this reason both governor and valve should be entirely independent of any other details, and the governor should be placed on the main shaft, so that no failure of gearing can affect it.

It should be designed so that when it commences to move it will fly to its extreme position on a slight increase of speed and generate ample power to move the gear. Some designs of safety governor valves are operated by a differential steam piston in a vertical cylinder, so proportioned that the valve is supported and held open by steam pressure. The safety governor opens a small valve exhausting the steam from the underside of the piston, so that the valve falls by reason of its weight and the steam pressure which is admitted on the top of the piston. Other designs utilize the main stop valve for the purpose, and they combine the usual hand wheel and spindle for opening the valve, with a steam piston or spring-loaded devices for closing the valve automatically when operated by the safety governor. For reasons already stated this appears to be undesirable. In case of failure both hand and automatic control is lost. The liability of steam relay systems to stick when not kept continually in motion neutralizes any advantages of these designs. A valve of the same design as the direct-connected main governor valve previously considered, and loaded with a spring or dead weight, and operated with a trip gear from the safety governor, offers less possibilities of failure, and is positive in its action. It can be so designed that before putting the machine on load the valve and gear can be tested by hand in a few seconds, thus insuring it being in working order. Butterfly safety valves have done good service on engines, but the rapidity with which a turbine gets away makes it desirable absolutely to cut off all steam, and this cannot be done with a valve of the kind.

Exhaust Connection.—The conditions are similar to those at

the steam inlet. If there is more than a very short length of horizontal piping it is desirable to anchor the bend below the turbine to the foundations. This prevents the expansion in the horizontal piping from exerting a twisting effort on the turbine cylinder. A corrugated-copper expansion pipe or wrought-iron bellows pipe must be provided between the bend and turbine cylinder to take up the vertical expansion.

Concluding Remarks.—It seems almost superfluous to insist on the necessity of positively locking all pins on governor gear, and especially all bolts, nuts and studs in steam spaces, on valve seats, spindles, &c., yet many shut-downs have occurred through neglect of this point. All castings subjected to superheated steam should be annealed after rough machining and before finishing, otherwise permanent distortion will often occur when put in service. Special attention must be given in designing steam chests, valves, &c., to obtain forms which will expand evenly and retain their shape. It may be argued that many troubles have been experienced which are confined entirely to the turbine, but, considering the vast amount of pioneer work which has been successfully accomplished, and the world-wide development which is going forward, it is certain that the difficulties will be surmounted. —"The Engineer."

THORNYCROFT PARAFFIN MOTOR FOR THE ROYAL ITALIAN NAVY.

The engines illustrated are designed to be installed in two twin-screw submarine boats and are constructed in four-cylinder units, bolted together, making eight cylinders on each shaft. The dimensions of the cylinders are 12-inch diameter by 8-inch stroke. They are totally enclosed, and lubrication is forced to all bearings, those on the crank shaft and also the bottom of the crank case, being water cooled. In addition to this, the pistons and crank case generally are continuously cooled by sucking cold air, which is drawn through by an exhausting fan.

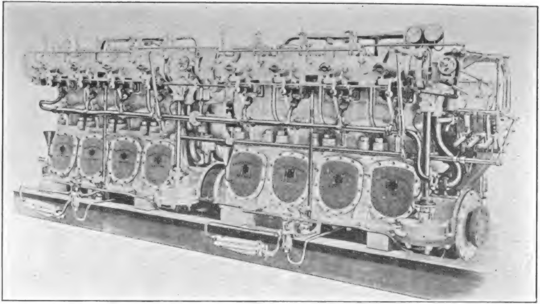
Facilities are provided for the removal and replacement of the pistons and connecting rods through the doors in front of the engine, thus rendering removal of the cylinders and access from the back of the motor unnecessary, an advantageous feature for submarine boats.

Cooling water is circulated by a separately-driven centrifugal pump, driven by either an electric motor or a small oil motor using the same fuel as the main engine. A great advantage of this method is that the motor may be cooled more rapidly after running, in case examination or adjustment becomes necessary. The separate drive also allows of a close regulation of the quantity of water to suit the needs of the engine, according to the nature of fuel used.

The special paraffin vaporizer is fitted with a variable exhaust bypass so that the temperature may be exactly graduated to the needs of the particular fuel used. This is very essential, as the oils used for fuel vary so greatly in the amount of heat required to vaporize them, and excess of heat is as harmful as too little. With a proper regulation of heat the engine or vaporizer never requires to be cleaned as there is no tar deposit. Trouble on this score is absolutely non-existent with these engines.

An entirely novel feature is the reversing mechanism, replacing the usual method of using a double set of cams for running in either direction. The camshaft is so arranged that whichever direction the engine itself runs, the camshaft turns in one direction only, and to provide for this a reversible bevel drive, with positive clutches, is fitted. Starting in either direction is effected by means of compressed air, the valves controling which are cut off immediately the engine is firing. Low-tension magneto ignition and distributor are fitted in conjunction with a special form of make-and-break gear in the cylinders.

The consumption of fuel is very low, being about .7 pint of paraffin or petrol per brake horsepower per hour. The engines are designed with ample bearing surfaces and are in



Engines to be Installed in Submarine Boats of Italian Navy.

every way suitable for heavy, continuous service. The total weight per four-cylinder set is 70 cwt.

The following table of results of a three-hours' trial is of interest:

Trial of 1 and 2, 8-cylinder 12 inches diameter × 8 inches stroke. Reversing.

Fuel used, Phœbus Paraffin; S. G., 0.820.

Consumption, 0.66 pint per B.H.P. per hour.

Time from start. *Hours.*	B.H.P.	Revolutions.
0	324	550
½	328	555
1	340	590
1½	327	595
2	318	595
2½	318	600
3	324	600

The average revolutions per minute were 582.5, and the average power 325.5 B.H.P. The equipment for each boat will consist of two eight-cylinder sets, driving twin screws, and together developing 650 B.H.P. The boats in which they will be installed are of 150 tons displacement, and have a radius of action of 500 miles at 10 knots speed. Their dimensions are 98½ feet by 14½ feet. The table of trial results is that taken during an official trial in the presence of a commission of inspection from the Ministry of Marine, Italy. The consumption of fuel, which is ordinary paraffin or lamp oil, amounting to 0.66 pint per B.H.P. per hour, is claimed as extremely low for engines of this type.—"Page's Weekly."

ASSOCIATION NOTES.

The regular annual meeting of the Society was held in the Navy Department, Washington, D. C., December 26, 1907, for the purpose of electing officers for the year 1908.

A count of the votes received resulted in the election of the following officers:

President, Commander R. S. Griffin, U. S. Navy.

Secretary-Treasurer, Commander Theo. C. Fenton, U. S. Navy, Retired.

Members of the Council, Commander F. C. Bieg, U. S. Navy; Commander B. C. Bryan, U. S. Navy; Commander H. P. Norton, U. S. Navy.

The following is the statement of the Secretary-Treasurer for the year ending December 31, 1907:

Received 1907:		
Dues and subscriptions	$4,031.82	
Advertisements	1,755.54	
Sales	740.85	
Interest	268.17	
Total receipts		$6,796.38
Balance (Cash) January 1, 1907		1,733.47
		$8,529.85
Expended:		
Printing and stationery	$3,872.89	
Engraving	417.52	
Salary, Secretary-Treasurer	900.00	
Purchase of Journals	115.00	
Articles paid for	80.00	
General expenses, including employment of clerk, postage, expressage and incidentals	146.25	
Purchase of one (1) $1,000 bond, Washington Railway and Electric Co.	815.50	
Total expended		$6,347.16
Cash balance		2,182.69

Available assets of the Society, January 1, 1908:

Cash balance	$2,182.69
Six (6) $1,000 bonds (cost)	5,215.50
Total	$7,398.19
Total value, January 1, 1907, cash and bonds	6,133.47
Net gain for year 1907	$1,264.72

This statement was audited by a committee of the Council and found to be correct.

THEODORE C. FENTON,
Commander, U. S. N., Retired,
Secretary-Treasurer.

R. S. GRIFFIN, Commander, U. S. N.,
President.

U. S. BATTLESHIP "NEW HAMPSHIRE."

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U. S. S. *NEW HAMPSHIRE.*

DESCRIPTION AND OFFICIAL TRIALS.

BY WILLIAM ASHLEY LEAVITT, JR., ASSOCIATE.

The *New Hampshire* (Battleship No. 25) built by the New York Shipbuilding Company, Camden, New Jersey, is a first-class battleship of 16,000 tons trial displacement, authorized by Act of Congress, April 27th, 1904.

The contract was signed December 27th, 1904; first plate laid May 1st, 1905; hull launched June 30th, 1906; and the vessel delivered to the Government March 14th, 1908, or 16 days over the contract time of 38 months.

Upon delivery of the vessel a considerable amount of work, consisting principally of turret and ordnance details, was unfinished, but as the causes were due to Government changes from original plans, delivery of the vessel to the Government was authorized, the work to be done at the New York Navy Yard.

The contract price for the construction of the hull and

machinery was $3,748,000, of which sum $2,848,000 was allotted to hull and $900,000 for the propelling machinery and auxiliaries. The contract required an average speed of not less than 18 knots per hour for four consecutive hours over a measured course, at a mean draught of 24 feet 6 inches, corresponding to a displacement of 16,000 tons; and an additional endurance run in the open sea, under all boilers, for 24 consecutive hours, at an average of not less than two-thirds of the average horsepower developed on the four-hours' full-power trial. Due to this requirement, in order to minimize the element of risk on the 24-hour trial, it was consistent for contractors to maintain for the four-hour full-power trial a speed close to the minimum contract speed, which was done, but the vessel gave most satisfactory evidences of a fine margin of speed and reserve power when tried out over the measured mile during the standardization runs. The vessel is without any question one of the very best in the United States Navy, and the contractors are deserving of full credit for having turned out such an excellent piece of work.

OFFICIAL TRIALS.

The Navy Department having given permission to begin the official trials December 19th, 1907, the ship left Camden December 15th at 9.30 A. M., but on account of storm, fog, and delay incident to adjusting the compasses, did not clear the Delaware Capes until 2.30 P. M. December 16th, reaching a point off Monhegan Light, 2 hours run from Rockland, Maine, at 10.30 P. M. December 17th, or 32 hours for the run of 480 knots. The trip was devoid of interest except as regards the satisfactory performance of the propelling machinery, the average number of revolutions per minute being 100, except for one hour when a run at 124 revolutions under forced draft was made. This was the only speed run made before the Trial Board took charge and the official trials were made. December 18th was spent at anchor in Rockland Harbor, the Trial Board coming off to the ship in the afternoon for about an hour. December 19th being favorable

both as regards wind and sea, the standardization runs were made over the Government measured-mile course off Monhegan Island, the maximum speed attained being at the rate 20.056 knots, at 125.2 revolutions, developing 19,686 I.H.P.; and the average of the five runs at full power 18.72 knots at 125.22 revolutions, developing 19,652 I.H.P. The only items of note during these runs was a tendency to heat on the part of the F.L.P. port and H.P. starboard crank pins, and these brasses were removed and refitted previous to the four-hour trials.

On December 20th, at 7·15 P. M., the four-hour endurance run in open sea was made most successfully, the course being laid from the lower end of Monhegan Island, S.S.W. ¼ W. along the Atlantic Coast. The most remarkably close engine running was maintained throughout the four hours, the average variation being one-tenth of a revolution. The average number of revolutions for the starboard engine was 118.8; port engine, 118.7; the average of both engines being 118.75, developing 16,772 I.H.P. for the main engines, and a total of 17,267 I.H.P. for all of the machinery; and an average speed of 18.162 knots, the propeller slip being 13.99. The performance was most satisfactory in every respect; and the actual results are as close to the designed as theoretical and practical skill could ever be expected to come. At the conclusion of the four-hour run at 11·15 P. M., in order to make the Delaware Capes on the 24-hour run, time was wasted at slow speed until 5·15 A. M., December 21st, when the 24-hour run began. This run was without incident, and was most successful, the average revolutions being 109.59.

Below will be found general data of the three trial runs in the order mentioned.

STANDARDIZATION.

For the purpose of standardizing the screws thirteen runs were made over the measured-mile course off Monhegan Island, Maine, December 19, 1907, the usual fourteenth run not be made on account of darkness at 4 P. M., making it im-

possible to see the ranges. The weather was clear and cool, with moderate to gentle breeze and smooth sea.

Previous to the starting of the standardization runs the draught was taken and found to be—

Forward, feet and inches	23–06$\frac{1}{4}$
Aft, feet and inches	25–07$\frac{1}{2}$
Mean, feet and inches	24–06$\frac{7}{8}$
Corresponding displacement, tons	16,071

These runs gave the data from which the curves on Plate I were plotted.

After the standardization run the draught was—

Forward, feet and inches	23–04$\frac{3}{4}$
Aft, feet and inches	25–06
Mean, feet and inches	24–05$\frac{3}{8}$
Corresponding displacement, tons	15,976

DATA FOR FOUR-HOUR RUN.

Draught at beginning of trial, forward, feet and inches		23–08$\frac{5}{8}$
aft, feet and inches		25–09$\frac{1}{4}$
Mean draught at beginning of trial, feet and inches		24–08$\frac{15}{16}$
Corresponding displacement at mean draught at beginning of trial, tons	16,200	
Mean draught at end of trial, feet and inches (11:15 P. M.), estimated		24–07$\frac{1}{2}$
Corresponding displacement at mean draught during trial, tons,	16,145	
Speed of ship, in knots per hour		18.162

	Starboard.	*Port.*
Slip of propellers, in per cent. of their speed	14.02	13.95

PERFORMANCE—FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Maximum steam pressure of boilers, pounds	262.0	
Mean steam pressure at boilers, pounds	246.0	
Maximum steam pressure of engines, pounds, H.P. (chest)	245.0	240.0
Mean steam pressure at engines, pounds	230.0	233.0
H.P. steam chest, gauge, lbs...	223.0	221.0
1st receiver (absolute), pounds,	94.0	92.0
2d receiver (absolute), pounds,	33.0	31.4

	Starboard.	Port.
Vacuum in condensers, inches of mercury, mean	25.5	25.7
maximum	25.5	26.4

Temperatures. (Average of one-half hourly observations.)

Injection, degrees	42.0	42.0
Discharge, degrees	95.0	97.0
Hotwell, degrees	56.0	58.0
Feed water, degrees	163.0	139.0
Engine room, upper platform, degrees	Cool	
working platform, degrees	Cool	
Fireroom, above gratings, degrees	...	
working level, degrees	72.0	
Smoke stacks, average, degrees	...	

Revolutions or Double Strokes per Minute. (Average of one-half hourly observations.)

Average revolutions, main engines, per minute	118.8	118.7
Mean revolutions, both engines, per minute	118.75	
Pumps, main air	30.0	28.0
circulating	159.0	145.0
feed, d. s., per minute	34.0	24.6
fire and bilge	46.0	31.0
dynamo condenser, air and circulating	...	...
Dynamos	350.0	
Blower engines	227.4	
Air pressure in firerooms, in inches of water, mean	.49	

Mean Effective Pressures in Cylinders, in Pounds Per Square Inch. (Averages of cards taken at half hourly periods.)

Main engines, H.P. cylinder	111.5	111.3
I.P. cylinder	44.7	43.4
F.L.P. cylinder	18.0	18.8
A.L.P. cylinder	18.2	17.5
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	50.4	49.9

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	2,596.0	2,591.0
I.P. cylinder	2,814.0	2,731.0
F.L.P. cylinder	1,497.0	1,566.0
A.L.P. cylinder	1,519.0	1,458.0
total	8,426.0	8,346.0

	Starboard.	Port.
Collective H.P. of both main engines	16,772.0	
Air pumps, main	17.0	
Circulating pumps, main	108.0	
Feed pumps, main	201.0	
Dynamo condenser, air and circulating pumps	...	
Fire and bilge pumps	7.0	
Forced-draft blowers	42.0	
Dynamo engines	104.0	
Total for auxiliaries	495.0	
Collective I.H.P. main engines, air, circulating and feed pumps	17,100	
main and auxiliary engines in operation	17,267	

COAL.

Kind and quality used on trial : Pocahontas hand-picked, excellent.
Pounds per hour, main and auxiliary engines, during trial.............. 29,932

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	15.7
main engines, air, circulating and feed pumps, per square foot of grate surface	15.54
main engines, air, circulating and feed pumps, per square foot of heating surface	2.73
Pounds of coal per I.H.P. per hour, collective, main engines, air, circulating and feed pumps	1.785
I.H.P. per hour, all machinery in operation	1.773
square foot of grate surface, per hour	27.21
square foot of heating surface, per hour	.635
Cooling surface (main condenser), square feet per I.H.P. (total)	1.221
Heating surface, square feet per I.H.P. (total)	2.728

DATA FOR 24-HOUR RUN.

	Starboard.	Port.
Maximum average revolutions per minute for 60-minute period	112.6	112.1
Average revolutions per minute, 24 hours	109.85	109.32
Mean revolutions per minute, both engines	109.59	
Maximum steam pressure at boilers, in pounds	210	
Average steam pressure at boilers, in pounds	192	
Maximum steam pressure at engines, in pounds	196.0	190.0
Average steam pressure at engines	180.1	178.7
Maximum vacuum, each engine	26.6	25.6
Average vacuum, each engine	26.3	25.2
Collective, I.H.P. of all main engines	12,322	

	Starboard.	Port.
Collective, main engine, air circulating, feed and hotwell pumps	12,565	
Collective, main and all auxiliary engines in operation during trial	12,715	
Kind and quality of coal used on trial	Pocahontas, run of mine.	
Average pounds of coal used per hour during trial	24,583	
Pounds of coal per hour by main and all auxiliary engines in operation during trial per I.H.P.	1.933	
Pounds of coal per hour used by main engines, air, circulating, feed and hotwell pumps, per I.H.P.	1.956	
Pounds of coal per hour used by main engines alone per I.H.P.	1.994	
Speed of ship, in knots per hour	17.053	
Slip of propellers, in per centum of their own speed	12.60	12.19

INSPECTION AFTER TRIAL.

Summary of Findings of the Board.

Removed all valves of main engines; found same in good condition.

Opened main cylinders and removed rings of H.P. and I.P. pistons; found same in good condition.

Stripped S.H.P. crosshead and P.L.P. and P.I.P. crosshead and found same in good condition.

Stripped S.H.P. and S.A.L.P. crank pins and P.H.P. and forward P.L.P. crank pins. The brasses of S.H.P. and P.H.P. need refitting and S.A.L.P. crank pin needs dressing. The others were found in good condition.

Lifted caps of starboard No. 1 and port No. 4 crank-shaft bearings and found brasses and pins all O. K.

Opened main and auxiliary condensers and filled fresh-water side with water. Found no leakage of tubes, and condensers were clean as far as could be examined.

Opened steam and water ends and valve-chest chambers of main feed pumps; same for one auxiliary feed pump in fire-room. Found everything in good condition.

Opened steam and water ends and valve chambers of main air pumps; found same in good condition.

Opened steam cylinders of circulating-pump engines; found same in good condition.

Opened steam and water cylinders and valve-chest chambers of one fire and bilge pump; found same in good condition.

Emptied all boilers except A, which was in use for auxiliary purposes. Opened steam drums, examined all furnaces, tubes (fire side), inside of steam drums of all boilers, and they were found in good condition. Four-inch tubes above furnaces were generally straight; a few were bowed from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch. Examined also interior of one four-inch tube and four two-inch tubes in all boilers except A. These were found clean and in good condition. A number of grate bars in all boilers were found burned and in bad condition; these require renewal before the ship is accepted by the Government. Steam was on boiler A for auxiliary purposes during the inspection.

Slip joints that were installed on main feed lines near feed-water heaters worked perfectly satisfactory during the trial and were tight.

Examined one blower engine in No. 3 fireroom; was found in good condition.

PRINCIPAL DIMENSIONS OF HULL.

Length between perpendiculars, feet and inches	450–0
on load water line (24 feet 6 inches), feet and inches	450–0
over all, feet and inches	456–04
of straight keel, feet and inches	362–0
Projection forward of F.P., feet and inches	6–04
aft of A.P., feet and inches	0–00
Breadth, extreme, at L.W.L., outside of armor, feet and inches	76–10
molded, feet and inches	76–05½
Depth, molded, main deck, at side, M.S., feet and inches	43–01⅝
upper deck, at side, M.S., feet and inches	50–07⅜
Ratio of length to beam	5.94
Displacement per inch, at L.W.L., tons of S.W	63.2
Area of midship section, square feet	1,811
L.W.L. plane, square feet	26,590
wetted surface, square feet	44,000

TANKS.

CAPACITIES OF FRESH-WATER TANKS.

Tank No.	Compt.	Frames.	Location.	Side.	Capacity.		
					Gallons.	S.W.	F.W.
1	...	20-23	Upper Plat.	C.L.	1,250	...	4.6
2	...	20-23	Upper Plat.	S.	3,150	...	11.7
3	...	20-23	Upper Plat.	P.	3,150	...	11.7
4	...	20-23	Upper Plat.	C.L.	2,550	...	9.5
5	...	98-101	Hold	P.	2,550	...	9.5
6	...	98-101	Hold	S.	2,550	...	9.5
1 Res.	...	37-39	Upper	C.L.	1,020	...	3.8
2 Res.	...	72-74	Upper	C.L.	1,020	...	3.8
				Total	17,240	...	64.1

CAPACITIES OF RESERVE-FEED WATER TANKS.

...	B-94	58-61	...	Port	4,937	...	18.3
...	B-95	58-61	...	Stbd.	4,937	...	18.3
...	B-96	61-64	...	Port	4,937	...	18.3
...	B-97	61-64	...	Stbd.	4,937	...	18.3
...	B-98	64-67	...	Port	4,937	...	18.3
...	B-99	64-67	...	Stbd.	4,937	...	18.3
				Total	29,622	...	109.8

CAPACITIES OF FEED AND FILTER TANKS.

...	C-1	80-83	Engine room	P.	5,000	...	...
...	C-2	80-83	Engine room	S.	5,000	...	...
				Total	10,000	...	...

CAPACITIES OF TRIMMING TANKS.

...	A-1	Stem 3	...	P.S.	...	17.6	17.1
...	A-2	3-5	...	P.S.	...	29.3	28.5
...	D-11	101-104	...	P.S.	...	58.3	56.7
...	D-12	104 Stern	...	P.S.	...	39.9	38.8
				Total	...	145.1	141.1

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS.

Compartment.	Frames.	Side.	Cu. ft.	Tons.	
				F.W.	S.W.
A-94	12-16	P. and S.	1,690	46.9	48.2
A-95	16-20	P. and S.	2,090	58.0	59.6
A-96	20-23	P. and S.	1,840	51.1	52.6
A-97	23-26	P. and S.	1,960	54.4	56.0
A-98	26-30	P. and S.	2,775	77.0	79.2
A-99	30-35	P. and S.	3,610	100.2	103.1
B-80	35-37	P. and S.	1,720	47.7	49.3
B-81	37-40	P. and S.	2,630	73.0	75.0
B-82	40-44	P. and S.	2,700	75.0	77.0
B-83	43-46	P. and S.	2,735	75.9	78.1
B-84	46-49	P. and S.	2,775	77.0	79.2
B-85	49-52	P. and S.	2,780	77.2	79.4
B-86	52-55	P. and S.	2,790	77.5	79.7
B-87	55-58	P. and S.	2,790	77.5	79.7
B-88	58-61	Port	715	19.8	20.4
B-89	58-61	Starboard	715	19.8	20.4
B-90	61-64	Port	715	19.8	20.4
B-91	61-64	Starboard	715	19.8	20.4
B-92	64-67	Port	715	19.8	20.4
B-93	64-67	Starboard	715	19.8	20.4
C-95	67-71	P. and S.	3,660	101.6	104.5
C-96	71-74	P. and S.	2,674	74.2	76.3
C-97	74-77	P. and S.	2,629	73.0	75.1
C-98	77-80	P. and S.	2,590	71.9	74.0
C-99	80-83	P. and S.	2,520	70.0	72.0
D-96	83-87	P. and S.	2,830	78.6	80.8
D-97	87-90	P. and S.	2,010	55.8	57.4
D-98	90-94	P. and S.	2,440	67.7	69.6
D-99	94-98	P. and S.	2,700	75.0	77.0
		Total	63,228	1,755.0	1,805.2

MAIN ENGINES.

There are two main engines, right and left-hand, outboard turning when going ahead, each in a watertight compartment. They are of the vertical, inverted, direct-acting, four-cylinder, triple-expansion type, designed to develop about 16,500 I.H.P. at about 120 R.P.M., with a steam pressure of 250 pounds at the H.P. cylinder. The arrangement of cylinders, beginning forward, is forward L.P., H.P. and I.P., and after L.P. respectively; the F.L.P. and H.P. and A.L.P. and I.P. being bolted together, thus allowing freedom for expansion between the H.P. and I.P. cylinders in fore-and-aft and vertical planes, while a system of tie rods and

braces prevent fore-and-aft and athwartship motion to the engines as a body. The material used for the cylinders is cast iron, fitted with close-grained, hard cast-iron piston and valve-chest liners, the ¾-inch space between the casings and piston liners being utilized as the steam jacket, the top and bottom heads of the I.P. and L.P. cylinders also being jacketed. Steam for the jackets is taken from the boiler side of the main-engine throttle valve, and passes successively through the cylinders, spring-reducing valves at the I.P. and L.P. cylinders, allowing a maximum steam pressure of 80 and 60 pounds respectively. Each end of the piston valves is fitted with a packing ring of hard cast iron, made practically solid, being turned larger than the bore of the valve-chest liners, cut obliquely, the abutting ends bolted together and finished to fit the liners. The body of the H.P. valve is cast iron, and those of the I.P. and L.P. valves, steel pipe with cast iron heads. The H.P. valve stem is connected to the link block, and the I.P. and L.P. stems to a cast-steel crosshead which is connected to the link block, the Stephenson double-bar link motion, with adjustable cut-off, being used. There are five graduations for points of cut-off on each reverse-shaft arm, and are for the ahead motion only.

The cylinders are supported by a framing consisting of twelve forged-steel columns, 5½ inches diameter, flanged top and bottom for bolting to the cylinders and bed plate; each atwarthship pair of columns being trussed by X-braces, and stiffened fore and aft by horizontal and diagonal tie rods leading from the middle pairs of columns, thus offering no resistance to cylinder expansion.

The crosshead guides, which are of cast-iron, are bolted at the top to facings provided on the cylinders and at the bottom to cast-steel I-section strongbacks carried by the engine framing. The guides, which are of the slipper type, are hollow for the circulation of water to keep them cool.

The bed plates are of cast-steel, made in three sections, flanged and securely bolted together by body-bound bolts.

Each bedplate when assembled consists of two longitudinal and six cross girders of I-section, well stiffened by ribs, and furnishes the seatings for the crank-shaft bearings, engine framing and turning engine. Body-bound bolts secure the bedplates to the keelsons, forged-steel washers being fitted at each bolt between the bedplate and the keelson, the space between the washers being filled in with yellow pine.

The crank shaft is arranged with the cranks 90 degrees apart and is in two sections, the forward L.P. and H.P. being in one, and the I.P. and after L.P. on the other, the sequence of cranks being H.P., I.P., F.L.P. and A.L.P.

The upper ends of the connecting rods are forked for the crosshead brasses; these brasses and those of the crank pin being lined with white metal. Crank shafts and connecting rods are high-grade machinery forgings. The pistons are conical shaped, rough machined all over, the material of the H.P. being cast iron, and that of the I.P. and L.P. cast steel, the followers in each case being of the same material. The pistons are bored taper to fit the rods, and have a square counterbore on the under side to suit the shoulder on the piston rods. Pistons are secured to the rods by steel nuts, locked in place by plates bolted to the piston.

The packing rings are of hard cast iron, being practically solid, having been cut obliquely for machining and the ends clamped solidly together; lugs cast on the back of the rings limit the play, the bore being ⅛-inch greater than the corresponding bore of the piston.

The piston rods are high grade, and the crossheads and slippers class "A" forged steel, the slippers being faced with white metal. The ends of the rods are tapered to fit the pistons and crossheads, and the slippers are bolted to the crossheads.

The reversing engine is located inboard and is bolted to the top of the H.P. cylinder. There is an oil-control cylinder of brass connected to the steam cylinder by wrought-steel stanchions which serve as crosshead guides. The reverse shaft is also on the inboard side of the engines, near the top

of the engine framing, and is connected to the crosshead of the reversing engine by two forged-steel connecting rods. Differential levers control the valve motion.

The turning engine is located inboard on the after end of the main-engine bedplate. The shaft carries a worm that engages a worm wheel carried by an inclined shaft, at the lower end of which is another worm that engages the driving worm wheel located on the coupling flanges between the crank and thrust shafts. The second worm is keyed to the inclined shaft by means of a feather, but may be moved vertically to engage or disengage the worm wheel on the crank shaft. A square for a ratchet, for turning by hand, has been provided on the after end of the turning-engine shaft.

MAIN ENGINE DATA.

Cylinder Data.

	H.P.	I.P.	L.P.
Diameter, inches	$32\frac{1}{4}$	53	61
Stroke, inches	48	48	48
Thickness of body, inches	$1\frac{3}{4}$	$1\frac{7}{16}$	$1\frac{5}{16}$
liner, inches	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{2}$
jacket space, inch	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
valve chest, inches	$1\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{1}{8}$
Number of studs in cylinder covers	36	42	40
Diameter of studs in cylinder covers, inches	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
Pitch of studs in cylinder covers, inches	$4\frac{5}{8}$	5	$5\frac{7}{8}$
Number of studs in valve-chest covers	18	18	16
Diameter of studs in valve-chest covers, inches	1	1	1
Pitch of studs in valve-chest covers, inches	$4\frac{3}{8}$	$4\frac{5}{8}$	$5\frac{1}{4}$
Number of tap bolts in piston liners	24	36	36
Diameter of tap bolts in piston liners, inch	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$
Pitch of tap bolts in piston liners, inches	$4\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$
Number of piston valves	1	2	2
Diameter of piston valves, top	$17\frac{1}{2}$	19	19
bottom	$17\frac{7}{16}$	$18\frac{15}{16}$	$18\frac{15}{16}$
Diameter of balance pistons, inches	9	9	9
Port area through valve-chest liner, top, inches	159.5	166.92	190.83
bottom, inches	158.7	166.22	190.04
Valve travel, inches	10	10	10

Valve Data for Port Engine.

Steam lead, linear, inches, top	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{16}$
bottom	$\frac{19}{32}$	$\frac{15}{16}$	$1\frac{1}{8}$
Full-gear cut-off, top, per cent	81.77	78.12	75.78
bottom, per cent	75.00	70.7	64.49

	H.P.	I.P.	L.P.
Earliest cut-off, top, per cent	58.85	54.68	45.5
bottom, per cent	48.37	46.15	41.5
Diameter of valve stem through gland, inches	2⅞	2⅞	2⅞
valve, inches	1⅞	1⅞	1⅞
Diameter of piston rods, inches	7½	...	7½
axial hole, inches	1½	3	4⅝
crosshead pins, inches	9¼	...	9¼
Length of crosshead pins, each, inches	9½	...	9½
slippers, inches	27½	...	27½
Width of crosshead slippers, inches	21	...	21
Lenth of backing surface, inches	27½	...	27½
Width of backing surface, each, inches	7⅜	...	7⅜
Length of connecting rod, center to center, inches	96	...	96
Diameter of connecting rod, top, inches	7	...	7
bottom, inches	8	...	8
hole, body, inches	1½	3⅜	4⅞
crosshead end, inches	1½	1½	1½
pin bolts, inches	3	...	3
Number of crosshead-pin bolts	4	...	4
Diameter of crank-pin bolts, inches	4	...	4
Number of crank-pin bolts	2	...	2
Diameter of crank pins, inches	17½	...	17½
Length of crank pins, inches	19	...	19
Diameter of hole in crank pins, inches	10	...	10
Diameter of hole in crank shaft, inches			9½
crank shaft, inches			17½
journals, inches			16½
coupling flanges, inches			28½
Width of crank-shaft coupling flanges, inches			3½
Number of coupling bolts, each section			8
Diameter of coupling bolts, inches			3½
pitch circle, inches			23¼
Width of crank webs, inches			19
Thickness of crank webs, inches			10¼
Number of main bearings			6
Length of main bearings, H.P., inches			19¼
I.P., inches			19½ and 10⅜
forward L.P., inches			19½
after L.P., inches			21½ and 19½
Diameter of main bearing bolts, inches			2⅝
Number of main bearing bolts per bearing			4
packing rings in pistons			1
Width of packing rings in pistons, inches			2½
Thickness of packing rings in pistons, inch			1
Number of follower studs in H.P. pistons			10
I.P. pistons			16
L.P. pistons			17
Diameter of follower studs, inches			1¼

Reversing Engines.

Diameter of steam cylinder, inches	13
oil cylinder, inches	7
steam-piston rod, inches	$2\frac{7}{8}$
oil-piston rod, inches	$2\frac{7}{8}$
Stroke, inches	$19\frac{5}{8}$
Length of connecting rods, feet and inches	$3–05\frac{15}{16}$
reverse levers, inches	$16\frac{1}{8}$
Diameter of reverse shaft, inches	7 and 6
bearings, inches	$6\frac{1}{4}$
Length of reverse-shaft bearings, inches	$8\frac{1}{4}$

Turning Engine.

Number of cylinders	2
Diameter of cylinders, inches	6
piston rods, inches	$1\frac{1}{2}$
valves, inches	$3\frac{1}{4}$
Stroke, inches	7
Valve travel, inches	$1\frac{1}{4}$
Crank angle, degrees	90
Area of crosshead slipper, inches	$16\frac{5}{8}$
Diameter of crosshead pin, inches	$1\frac{3}{4}$
Length of crosshead pin, inches	$2\frac{3}{8}$
Diameter of crank pin, inches	$2\frac{1}{4}$
Length of crank pin, inches	$2\frac{1}{4}$
Diameter of crank shaft, inches	$2\frac{1}{4}$
Length of crank-shaft bearings, inches	4 and 3
Diameter of pitch circle of worm, inches	$6\frac{13}{16}$
wheel, inches	$17\frac{3}{16}$
Number of teeth	36
Diameter of pitch circle of vertical worm, inches	9
worm wheel, inches	$64\frac{15}{32}$
Number of teeth	60
Diameter of vertical shaft, inches	$4\frac{1}{4}$
Area of step bearing, square inches	$38\frac{1}{4}$

ASSISTANT CYLINDERS.

An interesting and important feature of the propelling machinery is the Lovekin Improved Assistant Cylinders, applied to the valve gear of the main engines, this ship being the third in the United States Navy to be equipped with this simple and yet most effective device for overcoming the inertia primarily the cause of considerable wear upon the heavy valve gear working at high speeds with the

resulting item of expense for repairs, and an unnecessary amount of vibration, so annoying at any time and especially so on shipboard.

The highly satisfactory results obtained were anticipated, as the cylinders had proven their usefulness upon the armored cruiser *Washington* and battleship *Kansas* and were the subject of an exhaustive article at that time.

For results obtained upon the *Kansas*, see Volume XIX, No. 2, for the work done by the assistant cylinders on the port H.P. valve gear.

Interested readers will be well repaid by consulting the following references: "Balance Cylinders, Theoretically and Practically Considered," "Performance of the Assistant Cylinders of the *Washington*, and JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. XVI, No. 3; XVII, No. 3; XVIII, No. 3, and "The Balancing of Valve Gears, "Journal of the Society of Naval Architects and Marine Engineers," Nov., 1902.

SHAFTING AND THRUST BEARING.

The shafting is arranged in four sections, as follows: Thrust, line, stern tube and propeller, all of Class "A" forged steel. The line and stern-tube shafts are coupled as follows: Two forged-steel collars fit on the end of the stern-tube shaft, secured to prevent turning by four keys, and into a circumferential groove between the collars near the end of the shaft is fitted a pressure ring made in four sections, the coupling bolts passing through the steel collars and the flange on the thrust shaft. The stern-tube and propeller shafts are coupled as follows: The ends of the shafts are joined by a locking ring, over which is a long clamp in halves, each half held in place on the shafts by a longitudinal key, and the two sections of the clamp coupling secured by fitted bolts.

The bodies of the stern-tube and propeller shafts are covered with composition watertight casings; and each outboard coupling is covered with a cast-steel casing filled with melted pitch.

The thrust bearing is of the horseshoe type, with a steady bearing at each end, fitted with glands to prevent the escape of oil. The body is of cast iron, so shaped as to form an oil reservoir, and the horseshoes are of cast steel, made hollow for the oil and water service. They are faced with white metal, and have oil grooves on the bearing surface.

DATA FOR SHAFTING.

Diameter of thrust-shaft, inches	15¼ and 15⅝
hole, inches	9¼
Number of thrust-shaft collars	12
Outside diameter of thrust-shaft collars, inches	24½
Width of thrust-shaft collars, inches	2
space of thrust-shaft collars, inches	4
Length of thrust-shaft bearings, inches	18
Number of thrust shoes	12
Diameter of thrust side rods, inches	3⅝
line shafting, inches	15¼
stern-tube shafting, inches	16¼
shaft hole, inches	9½
Length of stern tube shaft forward bearing, inches	54
after bearing, inches	54½
Diameter of propeller shaft, inches	16¼
hole, inches	9¼
Length of strut bearing, inches	51
Diameter of thrust-shaft coupling flange, inches	28½
Thickness of thrust-shaft coupling flange, inches	3½
Number of thrust-shaft coupling bolts	8
Diameter of thrust-shaft coupling bolts, inches	3½
pitch circle, inches	23¼
Length of collars on stern-tube shaft, inches	3⅝ and 9⅝
Diameter of collars on stern-tube shaft (inside), inches	16¼
Number of keys	4
Length of keys, inches	14¼
Width of keys, inches	2¼
Depth of keys, inches	1⅛
Thickness of pressure ring, inches	1 and 1¼
Inside diameter of pressure ring, inches	15
Length of outboard coupling clamp, inches	52
Outside diameter of outboard coupling sleeve, inches	21⅛
Width of longitudinal keys, inches	2½
Depth of longitudinal keys, inches	1⅛
Width of locking ring, inches	4
Outside diameter of locking ring, inches	15
Number of bolts	16
Diameter of bolts, inches	2

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PROPELLERS.

The hub is fitted on the tapered end of the propeller shaft and held in place by one longitudinal key and a composition nut on the end of the shaft, the nut being threaded the reverse of the direction of the propeller. The nut is locked in place and covered with a composition cap bolted watertight to the hub. The blades fit into tapered recesses in the hub, being held in place by rolled manganese tap bolts, composition chocks being fitted around the bodies of the bolts to keep the blades from shifting after being set to the desired pitch. The bolt holes in the hub are oval in shape and allow a pitch adjustment of one foot either way. The propellers were accurately balanced, and each blade was made a true surface on both faces by machining, grinding and polishing. The material for blades and hubs is manganese-bronze. The spare blades have had the driving faces machined to a true surface by a machine specially designed for this purpose, the backing face being treated as above. The results obtained from a change of blades would be of interest.

DATA FOR ONE PROPELLER.

Number of blades	3
Diameter of propeller, feet and inches	17–03½
Pitch for official trial, feet and inches	18–0
maximum, feet and inches	19–0
minimum, feet and inches	17–0
Ratio of pitch to diameter	1.04
Helicoidal area, square feet	85.68
Projected area, square feet	73.02
Disc area, square feet	234.83
Ratio projected to disc area	.31
Area of immersed midship-section, square feet	1,811.0
Ratio disk to immersed midship-section area	.259
projected to immersed midship-section area	.081
Number of tap bolts for blades	27
Diameter of tap bolts for blades, inches	3⅛
Length of tap bolts for blades under head, inches	6½
Width of longitudinal key, inches	3½
Thickness of longitudinal key, inches	2¼
Length of longitudinal key, inches	35
Diameter of shaft-nut thread, inches	9½
Length of shaft-nut thread, inches	9

Number of threads per inch	4
Immersion of tip of blade, inches	81½
Tip of blade above keel, inches	10

DATA FROM OFFICIAL TRIAL.

	Port.	*Stbd.*
Average revolutions per minute on course	118.7	118.8
Slip, per cent. of its own speed	13.95	14.02

WEIGHTS OF PROPELLING MACHINERY.

The contract weight of the propelling machinery and auxiliaries was 1,500 tons, the actual weight being 1,577.51 tons, or 25.86 tons overweight; thus entailing a loss of $12,930.00 to the contractors if the penalty of $500.00 per ton is enforced. Below will be found the weights in detail and the sum total.

	Pounds.
Cylinders of main engines	266,577
Shafting	187,938
Main-engine framing and bearings	217,276
Reciprocating parts of main engines	72,671
Main-engine valve gear	53,380
Main condensers	92,052
Main, air and circulating pumps	54,497
Propellers	54,346
Boilers	750,120
Boiler fittings	258,573
Smoke pipes and uptakes	335,558
Steam and exhaust piping and valves	104,442
Suction and discharge piping and valves	94,690
Lagging and clothing	46,900
Flooring, gratings, etc	99,737
Auxiliaries	124,702
Fittings and gear	87,740
Water	295,755
Stores, tools and spare parts	172,213
Miscellaneous machinery	164,454
Total	3,553,621

Total weight as above, in tons		1,577.51
Less:		
Contract weight, tons	1,500.00	
Authorized changes, tons	.08	
Spare crank-shaft and propeller blades, tons	16.14	
Water in evaporators and distillers, and feed and filter tanks, tons	35.43	1,551.65
Net weight in excess of contract weight, tons		25.86

BOILERS.

The boilers on this ship are of the Babcock & Wilcox type, and were designed, built and installed by this well known concern. The battery consists of twelve boilers placed two each in six watertight compartments, all compartments being symmetrically arranged.

Each boiler has one drum extending the full width of the boiler and is located within the casings, so that about one-fourth of the shell is in contact with the gases at the top of the combustion chamber. Immediately below the drum are the front headers, and at the back of the boilers are the back headers, connected by tubes set at an angle of 15 degrees.

The weight of the drum and front headers, etc., is carried by the furnace front, and that of the back headers by a light structural-steel girder that also forms a portion of the casing.

This is protected from the fire by a bridge wall of brick extending the full width of the furnaces. There are two of these of equal size, separated by a wall of rectangular water legs that extends from the lower row of tubes to a point just below the surface of the grate. The side walls are similarly constructed, and all are connected to a mud drum carried in the boiler front immediately below and connected to the front headers, thereby providing a constant circulation of water and affording excellent means for draining and blowing off.

The boiler casings are made of steel plates and shapes, fire brick and block magnesia being used for insulation. Front and back at the header space they are in the form of doors of such size that they may be easily removed for access to the inside of the tubes, and the sides are removable in sections for access to the baffle plates and for cleaning soot from the tubes.

Each furnace is provided with three furnace and two ash-pit doors, and the grate bars are of the ordinary common type, of such size and shape as to be handled by one man.

Boiler Drums.—The boiler drums are of open-hearth steel plate, having two seams which are butt-strapped inside and out. The heads are convex, the radius of which is equal to the inside diameter of the drums, and in each is a flanged

manhole shaped from the same plate. All butt straps were formed to the proper curvature of the drum under hydraulic pressure, the rivet holes being punched about ¼ inch smaller than the diameter of the rivets used, and then drilled out full size after the plates were rolled and assembled. After drilling, all burrs were cleaned off, the plates reassembled, with turned bolts holding the parts in place for riveting. Wrought-steel pads securely riveted to the drum shell are provided for attaching all valves and fittings.

The following external fittings are provided for each drum:

One 5-inch hand and steam-closing boiler stop valve.
One twin-spring safety valve, each valve 4½ inches in diameter.
Two 2½-inch stop valves for main and auxiliary feed.
Two 2½-inch check valves for main and auxiliary feed.
Two Klinger reflex water gauges with automatic fittings.
One 1½-inch surface-blow valve.
One ½-inch sentinel valve.
One ½-inch air valve.
One ¼-inch steam-gauge connection.
Three ⅜-inch try cocks.

The following internal fittings are provided:

One 6-inch brass dry pipe.
One 2½-inch main feed pipe.
One 2½-inch auxiliary feed pipe.
One 1½-inch pipe and scum pan for surface blow.
Zinc protectors and baskets.

Headers.—The headers are of forged-steel, forged in one piece into a rectangular section, having male and female sinuous side for nesting when assembled. The front side is provided with numerous handholes for access to the generating tubes. The covers for these handholes are of pressed steel, held in place by one stud, nut and dog. All holes for the

generating tubes and connecting nipples between headers and drums are bored and reamed the size of tubing used.

Tubes.—The generating tubes are straight and made of seamless cold-drawn steel. These and the header and drum nipples, which are of the same material, are rolled in place by the B. & W. patent expander. Only one nipple showed any sign of leak on the trial.

DATA FOR BOILERS.

Number of boilers	12
Length of drum, feet and inches	15-03
Inside diameter of drum, inches	42
Thickness of drum plate, inches	$\frac{21}{32}$
Heating surface per header and tubes, square feet	156.8
Total heating surface for one boiler, square feet	3,926.0
grate surface for one boiler, square feet	91.66
H.S. for all boilers, square feet	47,112.0
G.S. for all boilers, square feet	1,100.0
Ratio H.S. to G.S.	42.82
Per cent. of air space in grates	.50
Number of boilers per smoke pipe	4.
Height of smoke pipe above grate, feet and inches	92-11
Area through smoke pipe, square feet	53.46
Ratio G.S. to smoke-pipe area	6.85
Size of generating tubes, inches	2 and 4
Total number of headers, per boiler	25.
Thickness of 2-inch generating tubes, B.W.G	8.0
4-inch generating tubes, B.W.G	6.0
Exposed length of generating tubes, feet and inches	9-0
Number of 2-inch generating tubes per boiler	688.
4-inch generating tubes per boiler	53.
Inclination of tubes, degrees	15.0
Height of boiler, feet and inches	13-00¾
Length of boiler, feet and inches	10-01
Width of boiler, feet and inches	14-10½
Weight of one boiler complete, dry, pounds	62,510
water in one boiler, at middle cock, 59° F., pounds	16,206
one boiler complete, wet, pounds	78,716
Total weight of boilers, dry, pounds	750,120
water in boilers, pounds	194,472
boilers, wet, pounds	944,592
Ratio of weight of boilers dry to boilers wet	.794
Designed working pressure, pounds per square inch	265
Test pressure, pounds per square inch	400

MAIN STEAM LINE.

The main steam pipes are arranged symmetrically in two systems, one on each side of the center-line bulkhead. They are united in the engine rooms by an 8-inch cross-connecting pipe, with a valve worked from both sides of the center-line bulkhead. The main steam pipes are supplied directly from the auxiliary steam pipes by a 7-inch globe valve at the after end of each boiler room, consequently there are no main steam lines in the forward boiler compartments. From the forward and middle compartments the branches unite into a 9-inch pipe, which is increased to 11 inches at the junction of the connection from the after compartment. This diameter is carried aft through the after dynamo room to the engine rooms, passing through the main-engine separators, which are located on the center-line bulkhead in the forward end of each engine room directly under the protective deck. The same diameter is carried from the separators to the main-engine throttle, and between these points a main stop or cut-off valve is located at the separator, and the expansion in this line is taken care of by a balanced expansion joint anchored to the forward engine-room bulkhead. From a 6-inch nozzle on the separators a cross connection is led between the main and auxiliary steam lines. At the separators, nozzles are also provided for 5-inch branches to the receivers, 5-inch bleeder connection to main condensers.

Globe stop or cut-out valves are placed just forward of each junction, and all valves in the main steam line have by-pass valves attached to relieve them when jammed on their seats.

The pipes are of seamless drawn-steel tubing with rolled-steel flanges, the working pressure on the piping being 265 pounds per square inch.

The expansion of the main steam pipes in the firerooms and dynamo rooms is taken care of by an expansion joint in each compartment, and where pipe is bolted to athwartship bulkheads proper allowance has been made for expansion by making bolt holes oval.

When condensed steam is apt to accumulate, drain valves

are fitted and pipes led to automatic float traps, which discharge into condensers or feed tanks.

The piping is lagged with sectional magnesia covering with canvas sewed on and well painted and lagged with galvanized sheet iron.

AUXILIARY STEAM LINES.

The auxiliary steam lines are arranged in two systems, extending fore and aft through the boiler compartments, one on each side of the center-line bulkhead, directly under the main steam line. Each system is supplied directly from the boilers by connecting with the main stop valves of all boilers on its own side of ship through 5-inch branches. From the connection on the forward boiler in the forward boiler compartment the size of the pipe is carried 7 inches to the after end of the after boiler compartment, from which a 4-inch branch is taken on the port side to supply steam to the evaporating plant. Aft of this the pipe is reduced to 6½ inches diameter, and carried 6 inches through the dynamo room to the engine rooms, aft to the 4-inch connection to the dynamo engines, with stop or cut-out valves on the forward dynamo-room bulkhead.

With a valve at the forward engine-room bulkhead the auxiliary steam lines are carried along the inboard sides of the engine rooms, and the two systems are united by a 6-inch connection passing through the center-line bulkhead with a valve at the bulkhead.

Steam to the steering engine is supplied by a 4½-inch branch taken off of the auxiliary steam line in the engine room on the starboard side. The distributing castings in the engine room also supply steam to main feed pumps, main air pumps, main circulating-pump engines, engine-room, fire and bilge pumps, distiller circulating pumps, auxiliary air and circulating pumps, fresh-water pumps, oil pumps, turning and reversing engines, cylinder jackets, after heating system and galley, and connections for blowing out sea chests and boiling out condensers, feedwater heaters and grease extractors.

In the forward fireroom, just forward of the 5-inch connection to the forward boiler, the systems are reduced to 6 inches and fitted with cut-out valves. These 6-inch connections extend to the forward end of the compartment and pass through the center-line bulkhead, with a valve worked from both boiler rooms, thus forming a loop. At this forward cross connection are nozzles for 4-inch steam to dynamos, port and starboard sides; 4½-inch steam to auxiliaries forward of the firerooms, starboard side; 3-inch steam to heating system, port side; 1-inch steam to galley and pantries, port side; 2-inch steam to whistle and siren, port side.

In each boiler room the distributing castings supply steam to the auxiliary feed pumps, fireroom, fire and bilge pumps, blower engines, ash hoists, tube cleaners and connections for blowing out sea chests.

Stop valves are located on the forward side of athwartship bulkheads. The distributing castings are anchored directly to the center-line bulkhead, and the expansion in the pipes and boilers is taken care of by expansion joints, proper allowance having been made for connection on bulkheads by making bolt holes oval.

The material of pipes and flanges is the same as for main steam lines. Where condensation is apt to accumulate, drains are fitted and piped to automatic traps which discharge to condensers and feed tanks.

The pipes are lagged the same as the main steam lines.

MAIN CONDENSERS.

There is one main condenser in each engine room. They are 6 feet 7 inches in diameter by 15 feet 3 inches long by 13 feet between tube sheets. The shell plating is of steel, the water chests of composition, tubes of composition, 70 parts copper, 29 zinc, 1 tin; tube sheets of rolled Muntz metal, and the tube-supporting plates of sheet steel bushed with composition.

The forward water chest, being the one for the entrance and exit of the circulating water, has a division plate on the

center line of the condenser. Sizes of inlet and outlet are 18½ inches in diameter, the inlet nozzle being on the bottom. There are two exhaust nozzles each 22½ inches diameter.

DATA FOR ONE CONDENSER.

Number of tubes	4,816
B.W.G. of tubes	16
Outside diameter of tubes, inch	0⅝
Length of tubes between tube sheets, feet and inches	13–0
Number of supporting plates	2
Cooling surface, measured on outside of tubes, square feet	10,243
Ratio of cooling surface to total heating surface	.388

DATA FROM TRIAL.

	Starbd.		*Port.*
Temperature of injection water, degrees Fahrenheit		42.0	
discharge water, degrees Fahrenheit	95.0		97.0
Ratio of cooling surface to I.H.P. of main engines		1.22	

AUXILIARY CONDENSER.

There is one Davidson horizontal combined air and circulating pump with surface condenser in each engine room.

DATA.

Diameter of steam cylinder, inches	6
air cylinder, inches	10
water cylinder, inches	10
Length of stroke, inches	12
Diameter of circulating-pump suction, inches	5¼
discharge, inches	5¼
air-pump suction, inches	5
discharge (air pump), inches	3¼
Cooling surface of condenser, square feet	553
Number of tubes	441
Outside diameter of tubes, inches	0⅝
Length of tubes between tube sheets, inches	94
B.W.G. of tubes	16

MAIN AIR PUMPS.

The main air pumps are of twin, vertical-beam type, of Davidson design. They are located on the outboard side of the engine rooms, between the main condensers and the feed and filter tank. The discharge is into the filter portion of the feed tank, and there is a 5½-inch cross connection between the suction pipes from the main condensers.

DATA FOR ONE AIR PUMP.

Diameter of steam cylinders, each, inches	12
water cylinders, each, inches	30
Stroke, inches	18
Diameter of steam piston rods, inches	3
air piston rods, inches	3
suction nozzle, inches	11
Diameter of discharge nozzle, inches	9½

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average stroke, per minute	30.0	28.0
vacuum, inches	25.75	25.5
I.H.P.	17	

MAIN FEED PUMPS AND FEED SYSTEM.

There are two Davidson vertical-piston, double-acting, single, main feed pumps in each engine room, located on the center-line bulkhead forward of the operating platform. The suction is from the feed-tank connecting pipe, and the discharge from the two pumps, after uniting in one 5½-inch pipe, leads forward, passing through a grease extractor, which may be by-passed, and then through the feedwater heater, which also may be by-passed, into the after fireroom, reducing in size as each fireroom is passed.

DATA FOR ONE PUMP.

Diameter of steam cylinder, inches	16
water cylinder, inches	9½
Stroke, inches	12
Diameter of piston rods, inches	2½
piston valve, inches	6
suction nozzle, inches	4½
discharge nozzles, inches	4½
Material of water end	Composition.

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average double strokes, per minute	34.0	24.6
I.H.P., per minute	201.0	
pressure on feed main, pounds	315	295

FEED-WATER HEATER.

There is one horizontal feed-water heater on the discharge side of the main feed pumps, on the center-line bulkhead at the forward end of each engine room. The material of water heads is cast steel, and that of the tubes, tube sheets and shell, wrought steel.

DATA FOR ONE HEATER.

Total heating surface, measured on the outside of the tubes, square feet	830.0
Total number of tubes	756.
Outside diameter of tubes, inches	00⅝
Length of tubes between tube sheets, feet and inches	6-09
B.W.G. of tubes	16
Thickness of tube sheets, inches	00¾

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Temperature of feed water, degrees Fahrenheit	163	139
Pressure on feed line, pounds	315	295
Exhaust steam pressure in heaters, pounds	4	5

FEED AND FILTER TANKS.

The feed and filter tank is located on the outbound side of the after end of each engine room. It is rectangular in shape, and at the top is arranged as a filter, the filtering material being "loofa," which is placed between perforated plates, The filtering chamber is divided by vertical division plates. arranged so that the water flows under and over in succession. All material is steel, well galvanized before assembling.

Capacity of each feed and filter tank, gallons	5,000
Total capacity of feed and filter tanks, gallons	10,000

AUXILIARY FEED PUMPS.

In each starboard fireroom, located on the center-line bulkhead, is one Davidson vertical-piston, double-acting, single, auxiliary feed pump. Size of pumps, 12 inches by 8 inches, and 12-inch stroke.

The suctions are from the bottom blows, athwartship compartments, C. and R. pipes from ship's sides (after pump

only), feed suction pipe, reserve-feed water tanks, hose connection. The discharges are to the auxiliary-feed main, main and reserve-feed tanks (after pump only), hose connection, overboard, in port compartment, grate fire extinguisher.

FIREROOM, FIRE AND BILGE PUMPS.

In each port fireroom, located on the center-line bulkhead, is a Davidson vertical-piston, double-acting, single, fireroom fire and bilge pump. Size of pumps, 10 inches by 8 inches by 12 inches.

The suctions are from the bilges, adjacent athwartship compartment, sea, C. and R. drainage manifolds, hose connection. The discharges are to the fire main, overboard in same compartment, hose connection and fire extinguishers.

MAIN CIRCULATING PUMP AND ENGINE.

The main circulating pump and engine is located on the outboard side of the forward end of each engine room. The pump has three suctions, viz: the engine-room bilge, $18\frac{1}{2}$ inches; main drain, $15\frac{1}{2}$ inches, and main injection, $18\frac{1}{2}$ inches. The valves of the various systems are locked in such a manner that only one may be operated at a time.

DATA FOR ONE PUMP AND ENGINE.

Capacity of pump, gallons per minute	12,000	
Diameter of suction nozzle, inches	$18\frac{1}{2}$	
discharge nozzles, inches	$18\frac{1}{2}$	
impeller, inches	$56\frac{1}{2}$	
Width of top of blade, inches	$5\frac{1}{4}$	
Diameter of H.P. cylinder, inches	10	
L.P. cylinder, inches	20	
Stroke, inches	10	
Diameter of piston rods, inches	$2\frac{1}{4}$	
Length of connection rods, center to center, inches	25	
Valve travel, inches	3	
Angular advance, H.P., degrees	33	
L.P., degrees	34	
	Top.	*Bottom.*
Steam lead, H.P., inch	$\frac{1}{16}$	$\frac{1}{8}$
L.P., inch	$\frac{5}{32}$	$\frac{3}{16}$
Cut-off, H.P., per cent. of stroke	0.77	0.715
L.P., per cent. of stroke	0.78	0.71

Diameter of H.P. piston valve, inches	4¼
Size of L.P. slide valve, inches	1½x19¼
Diameter of crosshead pin, inches	3¼
Length of crosshead pin, inches	5
Diameter of crank pin, inches	4¼
Length of crank pin, inches	6¾
Diameter of crank shaft, inches	4¼
Length of bearings, inches	5¾x8 and 8
Crank angle, degrees	90
Area of crosshead slipper, square inches	60

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average revolutions per minute	159	145
Average I.H.P.	108	

EVAPORATING AND DISTILLING PLANT.

The evaporator rooms are located amidships port and starboard on the berth deck, forward of the engine-room hatches, the distillers being in the ventilator trunk to the starboard room on a level with the main deck.

The plant consists of three evaporators and two distillers, having a designed capacity of 16,500 gallons of potable water in twenty-four hours. The distiller circulating pumps are located in the forward end of each engine room, fresh-water and evaporator feed pumps in the starboard evaporator room.

The evaporator shells and heads are of steel plate, the front steam heads for the coils being of cast steel and the back heads of composition. The tubes are brass, rolled into Muntz metal tube sheets. Each evaporator is provided with steam gauges and relief valves for the shell and coils, also water columns, gauge cocks and blow-off valves.

The distillers are vertical and of the Bureau type. The shell is of cast iron, the covers and tube sheets of composition and tubes of brass, tinned inside and out. The tubes are expanded into tube sheets by rolling, and expansion is taken care of by having the bottom tube sheet made with a flange that works in a stuffing box. The circulating water enters at the bottom, passes through the tubes and is discharged at the top; the vapor enters the shell at a point close to the top tube sheet, the water leaving at a similar point near the

bottom tube sheet. Baffle plates are provided for the inlet nozzles for the circulating water and vapor.

The following pumps of the Davidson type are provided: Two distiller circulating, size 10 by 12 by 12 inches; one distiller fresh water, size 4½ by 5 by 6 inches; one evaporator feed, size 4½ by 5 by 6 inches.

Piping.—Steam for the evaporators and pumps is taken from a reducing valve located in the port evaporator room at the terminus of a branch from the auxiliary steam line. The vapor may be sent to the distillers or the auxiliary exhaust line, the evaporators being arranged for operation in single effect. The fresh water from the distillers passes through a meter into a small reservoir tank located in the evaporator room, from which it may drain by gravity to the main and reserve-feed tanks or may be pumped into these tanks or the fresh-water tanks. The distiller circulating pumps have an independent connection to the sea, and, in addition to discharging to the distillers, may discharge to the sanitary system or fire main.

A test was made of the plant when the ship was at sea December 17th, 1907. First each evaporator and one distiller was given a two-hour trial, and then the entire plant was run for one hour, thereby furnishing an equivalent full-capacity test of three hours. The discharge from the distillers was run into the reservoir tank, and a careful record kept of the number of full tanks. The water was tested for purity at frequent intervals with a solution of nitrate of silver, the concentration of water in the evaporators every half hour, and all other conditions recorded every fifteen minutes. The result of the test of the entire plant proved that better results would be obtained by adding another distiller, which was done after the vessel was delivered to the Government.

The following are the averages of the data obtained from the two-hour test of entire plant:

Steam pressure in evaporator coils, pounds	49.0
shells, pounds	13.0
at reducing valve, pounds	139.0

Pump strokes per minute for entire plant:	
Evaporator feed pump	9.5
Distiller circulating pump	43.5
Output of distilled water in three hours, gallons	2,499.0
Capacity of distilled water in twenty-four hours, gallons	19,992.0

DATA FOR ONE EVAPORATOR.

Heating surface, tubes only, square feet	277.0
Gallons of water evaporated per square foot of heating surface in twenty-four hours	24.05

DATA FOR ONE DISTILLER.

Cooling surface, tubes only, square feet	165.0
Gallons of water distilled per square foot of cooling surface in twenty-four hours	60.58
Gallons of water distilled in twenty-four hours	9,996.0
Temperature of sea water, degrees Fahrenheit	45.0
fresh-water discharge from distillers, degrees Fahrenheit	74.0
external air, degrees Fahrenheit	39.0
evaporator room, degrees Fahrenheit	84.0
Concentration of water in evaporators by hydrometer test, degrees Fahrenheit	.0$\frac{2}{31}$
Quality of water distilled	good
Height of water in evaporators above bottom of glass, inch	1.0

ELECTRIC PLANT.

RECIPROCATING INSTALLATION.

The electric plant in the after dynamo room consists of four 100-kilowatt generating sets (125-volt pressure at the terminals), direct connected to engines of the vertical, cross-compound, double-acting, enclosed type. Generators and engines are of the General Electric Company manufacture.

DATA.

Type of engines	Vertical cross compound.
Number of revolutions per minute	350
Steam pressure, pounds	150
Diameter of H.P. cylinder, inches	10
L.P. cylinder, inches	18
Length of stroke, inches	10
Diameter of piston rods, inches	2¼
Number of generators	4
Capacity of each generator, in kilowatts	100
Dynamos	10 pole, 125 volts.

DATA FOR CONDENSER.

Make	Davidson.
Type, horizontal, combined air and circulating pump, with surface condenser.	
Diameter of steam cylinder, inches	10
air cylinder, inches	14
water cylinders, inches	16
Length of stroke, inches	12
Cooling surface of condenser, square feet	970
Number of tubes	774
Outside of diameter of tubes, inch	00⅝
Length of tubes, inches	94
B.W.G. of tubes	16

FORWARD DYNAMO ROOM.

Turbo-Generating Installation.

In the forward dynamo room of the U. S. Battleship *New Hampshire* are located two direct-current turbo-generating units. They are of the horizontal Curtis type, and were built by the General Electric Company.

Each unit consists of a 200-kw., 3-stage, 1,700-r. p. m. turbine and a direct-connected 200-kw., 125-volt, 4-pole, direct-current generator.

The turbine is designed to have three stages or pressure divisions. In the first stage there are three rows of rotating buckets and two rows of reversing buckets known as intermediates. The intermediates, however, cover only a small portion of the periphery. In both the second and third stages there are two rows of rotating buckets and one of intermediates.

The steam enters each stage by expanding through a set of nozzles which are designed to give a certain drop in pressure and velocity to the steam entering the buckets. For the first stage the set of nozzles is fastened to the valve casing, and for the second and third stages the nozzles are cast into the stage partitions, or diaphragms, as they are called.

The wheel casing or body of the turbine is cylindrical in form, and all the radiating surface is neatly lagged with Russia iron. The casing is supported on a bed plate which is common to both the generator and turbine.

The wheel, or rotating buckets, are cut out of solid steel

arranged in segments. These segments are riveted to the wheel disc, and are so designed as to size, radius and number as to make a perfect wheel.

For protecting the buckets a steel band is riveted over the outer end, the riveting being done by means of upsetting the end of the bucket.

The wheel disc is riveted to the hub, which is keyed to the turbine shaft.

The turbine and the generator, while mounted on the same bed plate, are two distinct units, each unit having its own shaft supported by two bearings; the shafts being fastened together by means of a flexible coupling.

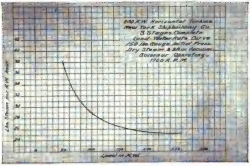
The bearings between the turbine and generator are arranged in one pillow block, and the flexible coupling is also placed in this pillow block, being entirely enclosed by the pillow-block cap.

The turbine shaft is made of nickel-steel, and is designed sufficiently rigid to withstand any tendency to whip which might be caused by excessive water getting into the turbine.

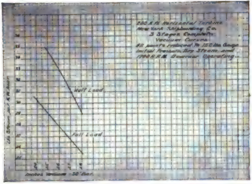
The intermediates or stationary buckets mentioned above are made of a composition metal. Over the inner end of the bucket is riveted, by upsetting the end of the buckets, a steel band for protection. The intermediates extend around the periphery only a sufficient distance to serve in diverting the steam from the nozzles. For instance, in the first stage the nozzles cover an arc of about one-eighth of the circumference of the wheel, and the intermediate buckets cover an arc but slightly longer than the arc of the nozzle.

The total clearance in an axial direction between the wheel buckets and intermediate buckets is sixty-five thousandths of an inch. In a radial direction the clearance is several inches, there being no limit theoretically to this clearance. This large clearance is employed so as to take care of any excessive amount of water which may accumulate in the turbine casing. Besides, there is a large drain box so arranged under the turbine as to drain the water from each and all stages.

For successful operation on high-speed apparatus, such as



LOAD WATER-RATE CURVE, TURBO-GENERATING PLANT.



VACUUM CURVE, TURBO-GENERATING PLANT.

turbines, a good oiling system is necessary. The oiling system for the above turbo-generating set is self-contained and is arranged as follows:

On the turbine end of the shaft is a small worm gear which operates at a moderate speed a small reciprocating oil pump of sufficient capacity to supply oil under pressure to all the bearings. It also supplies oil for operating the hydraulic gear. The pressure can be varied by means of a relief valve, but is generally maintained at about ten pounds per square inch. The oil is pumped from a small reservoir, located in the turbine base, through the bearings, returning through long pipes running the length of the base. The oil in the return pipes is cooled by means of water pipes. By the arrangement the oil is always kept cool, and may be used over and over for weeks without being changed.

The controlling governor is an inertia governor of the spring-and-weight type, and is located at the outer end of the turbine shaft. By means of levers and rods the governor is connected to the hydraulic cylinder, which in turn rotates a cam shaft. Cams mounted on the cam shaft operate successively the valves admitting steam to the various nozzles.

The system of hydraulic operation of the valves is the same as used on all large turbines made by the General Electric Company.

In regard to tests of this unit reference is made to cuts showing complete load curve, giving water rates in pounds per kilowatt hour. Also a vacuum curve at half load and full load, showing improvement gained by increase in vacuum.

The generator end of this unit consists of one armature core on which are two distinct and separate windings, each connected to its own commutator. The commutators are of standard shrink-ring turbine construction, the bars being mounted on a heavy cast-iron shell, this shell mounted directly on the shaft. The shaft is drilled through the center from one end with about a 3-inch hole, which latter furnishes air for the center of the armature core, where are located the ventilating

ducts extending out radially through the punchings. At one end of the shaft is mounted a centrifugal fan, the air from which is directed through the base and thrown directly against the surface of the commutators. This construction admits of using commutators of very moderate size.

Each winding of the armature has a normal capacity of 800 ampères at 125 volts. The two windings are operated in multiple, delivering 1,600 ampères at 125 volts.

There is one series field for compounding, and a commutating field, both of which are wired in series with the main 1,600-ampère load, so that even if slight unbalancing between the two armatures does occur there is proper compounding and compensation effected respectively by the series field and commutating field.

Each commutator is fitted with 11 brushes per stud, 4 studs, and there is mounted on the generator a galvanometer for the purpose of indicating to the attendant whether or not the commutators are dividing the load equally. If the brushes are properly set in the neutral of each commutator and the commutators are kept clean by occasional wiping with a canvas swab, the load will divide practically in halves between the commutators.

CONDENSING PLANT.

The condensing plant consists of one independent air pump, one centrifugal pump and engine and one surface condenser. The performance of the air pump was most satisfactory, on trial a constant vacuum of 26½ inches being maintained running both machines at full load.

DATA FOR AIR PUMP AND CONDENSER.

Make	Edwards.
Type	Vertical, single acting, plunger, flywheel, fitted with a Pickering governor.
Diameter of steam cylinder, inches	5
air cylinder, inches	12
Length of stroke, inches	10
Cooling surface of condenser, square feet	1,600

Number of tubes	1,277
Outside diameter of tubes, inch	00[illegible]
Length of tubes, inches	94
B.W.G. of tubes, inches	16

DATA FOR CIRCULATING PUMP AND ENGINE.

Capacity of pump, gallons per minute	1,800
Diameter of suction and discharge nozzles, inches	7
impeller, inches	30
Width of tip of blade, inches	1[illegible]
Diameter of steam cylinder, inches	5
Stroke, inches	5

In each dynamo room there is a main dynamo switch board which controls the generators in their respective rooms.

Steam is taken from the auxiliary steam line, and there is a steam separator in each room, which drains to a trap and the steam end of the air pump. The exhaust is into either the dynamo condenser, main or auxiliary condenser or the atmosphere.

Adjacent to each dynamo room there is a distribution room in which is installed a distribution switch board which is energized from either of the two main dynamo switch boards. From the distribution switch boards all the feeders which supply energy to the lighting and power systems are led.

The lighting system comprises a total allotment of 1,250 electric fixtures, not including special outlets for signal lanterns, truck lights, Ardois signal sets and outlets for special fixtures. There are two arc lamps in each of the engine rooms and firerooms.

There are four 30 and two 60-inch searchlights, two 30-inch being installed on the forward bridge, two on the after bridge, and one 60-inch on the searchlight platform on each of the masts. Separate and distinct from the lighting system is the power system, which supplies energy to all auxiliary machinery run by electric motors.

A complete system of wireless telegraphy is installed. Besides the lighting and power system there is an interior communication system, which includes call bells, general

alarms, shrill whistles, fire alarms, voice tubes, telegraphs and indicators.

A system of mechanical telegraph is also installed for communication between the bridge and engine room.

VENTILATION SYSTEM.

Artificial ventilation has been provided for all quarters, living spaces, passages, storerooms and magazines below gun deck, and also for air spaces in wake of boilers, engines and around magazines, for water closets and similar enclosures.

These systems have been arranged in such a way as to keep a continuous circulation of fresh air through the ship, the air being renewed in the various spaces approximately as follows:

Officers' quarters and crew space, berth deck outside of armor bulkheads, in from ten to twelve minutes.

Officers' quarters and crew space, berth deck inside of armor bulkheads, in about four minutes.

Water closets and crews' head, in about six minutes.

Storerooms and passages, in eight to twelve minutes.

Magazines, in from six to eight minutes.

Engine rooms and steering compartments, in about two minutes.

Evaporator rooms, in about two and one-half minutes.

Dynamo rooms, in about three-fourths of a minute.

This ventilation is provided by twenty-five electrically-driven fans, manufactured by the B. F. Sturtevant Company, Boston, Mass. Size, type and location given in table on next page.

The air, as supplied by these fans, running at their maximum speed, has a pressure of 5 pounds to the square foot and a velocity of approximately 2,000 feet per minute.

None of the principal longitudinal or transverse watertight bulkheads of the ship have been pierced by the ventilation ducts where possible to avoid it. No ducts have been carried through the transverse slopes of the protective deck, but in all

Set No.	Capac'y cu. ft. p. m.	Location. Deck.	Bet. Frames.	Pors.	Supply or exhaust.	Type of motor.	Type of fan.
1	6,000	Main	50-51	P.	Exhaust and supply	Enclosed	C. S. P. E. F.
2	6,000	do.	65-66	P.	do.	do.	do.
3	4,000	Gun	8-9	P.	Exhaust	do.	do.
4	600	do.	27-28	P.	do.	Open	C. C. S. E. F.
5	600	do.	65-66	P.	do.	do.	do.
6	600	do.	65-66	S.	do.	do.	do.
7	12,000	do.	74-76	P.	Supply	Enclosed	Double discharge. C. S. P. E. F.
8	12,000	do.	74-76	S.	do.	do.	do.
9	6,000	do.	79-80	P.	do.	Open	do.
10	6,000	do.	79-80	S.	do.	do.	do.
11	4,000	Berth	12-13	S.	do.	do.	do.
12	4,000	do.	21-22	S.	do.	do.	do.
13	4,000	do.	21-22	P.	do.	do.	do.
14	6,000	do.	34-35	S.	do.	do.	do.
15	6,000	do.	34-35	P.	do.	do.	do.
16	6,000	do.	37-38	S.	do.	do.	do.
17	6,000	do.	37-38	P.	do.	do.	do.
18	8,000	do.	71-72	S.	do.	Enclosed	do.
19	8,000	do.	71-72	P.	do.	do.	do.
20	2,500	do.	89-90	S.	do.	Open	do.
21	2,500	do.	89-90	P.	do.	do.	do.
22	4,000	do.	110-111	S.	do.	do.	do.
23	2,500	do.	110-111	P.	Exhaust	do.	do.
24	600	Gun	37-38	P.	do.	Enclosed	C. C. S. E. F.
25	2,500	S. E. R.	99-100	S.	Supply	do.	C. S. P. E. F.

Abbreviations—S. E. R. = Steering-engine room.
C. S. P. E. F. = Convertible steel-plate electric fan.
C. C. S. E. F. = Convertible cast-shell electric fan.

Total, 120,400 cubic feet per minute artificial ventilation.

cases through the flat and fore and aft slopes. Where ducts pass through protective deck they are made watertight to the highest practical point above the berth deck. All ducts passing through magazines are galvanized-steel seamless tubing, or built of heavy-gauge steel worked watertight. A natural exhaust duct, equal to the area of the mechanical supply duct, has been provided for each magazine, and located as far as practicable from the supply duct. The upper ends of these ducts are carried up close to gun deck and inside of the barbettes, where practicable, and terminate there with a goose neck, the lower end of which is bell mouthed and covered with wire mesh.

McCerry, or equally effective adjustable elbows, fitted with butterfly dampers, have been used for supply terminals in all quarters, living spaces and elsewhere. In the quarters they are nickel plated and elsewhere galvanized. All openings of these elbows are fitted with portable wire mesh. All other terminals are stationary.

All cowls have been installed where necessary for fan inlets or exhausts over bakery, galley, etc. Where any of the cowls interfere with the working of the guns, or where necessary for cleaning decks, they are made portable at the weather decks, and where such cowls are too high above weather decks to be easily reached they are fitted with operating gear worked from weather decks. Where required, cowls under awning have been provided with wire-mesh screens.

The ventilation for the coal bunkers has been arranged with ducts of galvanized-steel tubing or built of heavy-gauge material. Valves and dampers have been fitted for this system, and all openings into bunkers have been covered with wire mesh to keep coal out of ducts.

Especial attention has been paid to the ventilation arrangements provided to avoid the transmission of heat from the engine and boiler rooms to other parts of the vessel. In wake of the boiler rooms an air casing under protective deck and on the inboard side of berth-deck coal-bunker bulkheads has been fitted, and connected to the ship's ventilation for supply, and to the funnel casings for natural exhaust. The underside of protective deck within the engine rooms has been fitted with sheathing, with an air space allowed, and connected to the engine-room ventilation system for supply, and to the engine hatches for exhaust.

For ventilating the engine rooms the two fans are arranged to permit one-half the volume of each fan supplying the starboard engine room and the other half the port. Branches have been led from the mains to all working stations, platforms, air casing and corners of the rooms where required for efficient ventilation.

DRAINAGE SYSTEM.

The following is a general description of the drainage system, the features covered being as follows:

1. 15-inch main drain.
2. 5½-inch secondary drain.
3. 4⅝-inch double-bottom drain.
4. 4⅝-inch forward bilge drain.
5. 4⅝-inch aft bilge drain.
6. 4½-inch independent drain. (Bu. S. E.)
7. 5-inch independent drain. (Bu. S. E.)

Main Drain.—It is 15½ inches diameter throughout its entire length. It is located on the starboard side close to center line and extends from midway of forward fireroom to forward end of engine room, where it branches and runs athwartship, each branch connecting to a centrifugal pump.

A 15½-inch stop-check valve is located in each fire and engine room, those in starboard fire and engine room being in, and forming part of, main system; the valves in port firerooms being connected through center-line bulkhead to the line in starboard firerooms. All these 15½-inch stop-check valves are operated at valves and on berth deck in deck plates.

In the port engine room, at frame 73, there is a 5-inch connection between the main drain and C. and R. manifold No. 8, located at frame 75-76. This manifold is connected to the fire and bilge pumps in the fire and engine rooms.

Secondary Drain.—It is 5½-inches diameter throughout its entire length. It has connections to all fire and bilge pumps through the C. and R. and S. E. manifolds; also to the handy-billy pump manifold located on upper platform, forward, frames 34-35; after, frames 83-84. The forward connection is made directly to the secondary drain, while the after connection is made through C. and R. manifold No. 9 located in port engine room, frame 82-83.

The forward end connects to C. and R. manifold No. 1, located in port forward fireroom, frames 40-41, and the after

end to C. and R. manifold No. 9 in port engine room, frames 82-83.

The forward bilge drain, forward trimming-tank drain and chain-locker drain are taken by secondary drain through manifold No. 1, located in port forward fireroom, frames 40-41.

The after bilge drain and after trimming-tank drain are also taken by secondary drain through manifold No. 9, located in port engine room, frames 82-83.

There is a 5½-inch connection from bilge well in each fire and engine room to the secondary drain.

Double-Bottom Drain.—The double-bottom drain is divided into three sections, each being 4⅜ inches diameter.

The forward section runs on starboard side between frames 36 and 42, then shifts to port-side, frames 41-42, continues aft, draining double-bottom spaces under fireroom forward of bulkhead 58. It has a connection to C. and R. manifold No. 3, located in central port fireroom, frame 56-57; also to C. and R. manifold No. 4, located in aft port fireroom, frame 65-66.

The central section runs athwartship, frames 63-64, connecting to C. and R. manifold No. 5, located in after starboard fireroom, frame 64-65, and C. and R. manifold No. 6 in after port fireroom, frame 64-65. It drains the double-bottom compartments, outboard of the reserve-feed water tanks. This also has a connection to the forward section at frame 63-64.

The after section runs between frames 70 and 81 through the starboard engine room and drains the double-bottom compartments between frames 67 and 83. This has a connection to C. and R. manifold No. 7, located in starboard engine-room, frame 75-76, which has connection to fire and bilge pumps.

The double-bottom compartments are flooded through the S. E. manifolds connected to C. and R. manifolds by operating the stop-check lift valves in their respective manifolds.

Forward Bilge Drain.—It is 4⅜-inches diameter and drains all the double-bottom ends between frames 12 and 22 (double-bottom ends at frame 12), and the hold compartments between

frames 5 and 12. It connects to C. and R. manifold No. 1, located in forward port fireroom, frame 40-41, and is drained from there through the secondary drain.

After Bilge Drain.—It is 4⅜-inches diameter and drains all the double-bottom compartments between frames 83 and 98 (double-bottom ends at frame 98), and the hold compartments between frames 98 and 101. It connects to C. and R. manifold No. 9, located in port engine room, frame 82-83, and is drained from there through the secondary.

Independent Drains.—These drains come under the cognizance of Bureau of Steam Engineering. In the firerooms they are 4⅜ inches in diameter and run from the bilge wells to the fire and bilge pumps. These drains are fitted in each fireroom.

The independent drains in engine room are 5 inches in diameter and come under the cognizance of the Bureau of Steam Engineering. They are fitted in each engine room, and drain the bilge wells in shaft alley and engine room. The drains in the shaft alley connect to C. and R. manifold No. 10 port, No. 11 starboard, frame 86-87, and from there have a direct connection to Bureau of Steam Engineering manifold, which is connected to fire and bilge pumps in engine rooms.

C. AND R. MANIFOLDS—DRAINAGE SYSTEM.

Location.			
No.	Frame.	Port or Starboard.	
1	40-41	P.	In forward port fireroom.
2	47-48	P.	In forward port fireroom.
3	56-57	P.	In middle port fireroom.
4	65-66	P.	In after port fireroom.
5	64-65	S.	In after starboard fireroom.
6	64-65	P.	In after port fireroom.
7	75-76	S.	In starboard engine room.
8	75-76	P.	In port engine room.
9	82-83	P.	In port engine room.
10	86-87	P.	In port engine room.
11	86-87	S.	In starboard engine room.
12	34-35	P.	In passage, upper platform.
13	83-84	P.	In passage, upper platform.

TRIMMING TANKS—PUMPING AND DRAINAGE.

There are four trimming tanks, two forward and two aft. Those forward are flooded by a 5-inch sea connection, frame 7-6, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch globe valve, operated at valve and on berth deck in deck plates, frame 5-6.

Those aft are flooded by a 5-inch sea connection, frame 104-105, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch valve, operated at valve and on berth deck in deck plates, frame 104-105.

Draining.—The forward tanks are drained by a 3-inch pipe led to manifold No. 1, frame 40-41, and the after tanks by a 3-inch pipe led to manifold No. 9, frame 82-83. The extreme forward and after tanks are sluiced into adjacent compartments.

From these manifolds Nos. 1 and 9, water is handled by the secondary drain.

FIRE SYSTEM.

The following is a general description of the fire system.

The fire main is 6 inches diameter and is installed just below protective deck. It runs forward and aft on each side of center line of ship between frame 30-83. At the forward and after end, frame 30-31 and 82-83, the main is run athwartship, thus forming a complete circuit between frame 30-83.

A 4½-inch branch from the forward transverse 6-inch main, frame 30-31, is led forward on starboard side for fire plug between frame 10-30. A by-pass to the flushing system is taken from this branch, frame 17-18. A 5-inch branch is also taken from this 6-inch main on port side, for forward magazine-flooding system.

A 3½-inch branch from the aft transverse 6-inch main is led on starboard side, frame 82-83, to the underside of upper platform and then after to frame 99-100, for fire plugs aft. A 5-inch branch is also led from this 6-inch main on starboard side for the after magazine-flooding system.

There is a 4-inch connection to all fire and bilge pumps in

the firerooms, and a 5-inch connection to fire and bilge pumps in the engine rooms and to distiller circulating pumps.

A 1½-inch branch is fitted in engine rooms at bulkhead 83, port and starboard sides, for flushing stern tubes.

A 2½-inch branch is led from fire-main risers, frame 41-42, gun deck, for flushing ash chutes on main deck, frame 48-49. Also a 2½-inch branch from fire-main risers, frame 60-61, gun deck, for flushing ash chutes on main deck, frames 58-60.

Two relief valves are fitted in the system, one forward frame 14-15 gun deck, and one aft frame 82-83 berth deck; both at 100 pounds.

Cut-out valves for systems and risers below protective deck are operated at valve and on berth deck in deck plates.

All valves in the system are gate valves with indicators.

All hose connections are 2½ inches.

Zinc boxes are fitted in main system about 30 inches apart.

All pipe sizes are internal.

Firemain piping of copper sabined; all fittings of composition.

MAGAZINE FLOODING SYSTEMS.

The following is a general description of piping for the magazine flooding system:

There are two systems—one forward and one aft. Each system floods the magazine spaces in hold and on lower platform; the upper platform systems, forward and aft, being supplied by connections to fire main.

Forward System.—It is composed of two separate systems, one on starboard and one on port side, each being supplied by 8-inch sea connections between frame 21–23.

Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valves and on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

After System.—It is composed of two separate systems,

one on starboard and one on port side, each being supplied by 8-inch sea connections between frame 84–85 and 88–89. Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valve and on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

Upper Platform Systems.—These are connected to the fire main, as described thereunder, and in other particulars have the characteristics of the normal flooding systems.

All magazine flood valves are gate valves, operated at valve and on berth deck in deck plates.

All pipes are of copper, sabined.

All pipe sizes are internal.

Sprinkling Systems.—A sprinkling system is fitted in all magazines, excepting shell rooms and spaces in the hold. It consists, in the magazines, of 2½-inch brass pipe perforated on the under side, so that each powder tank can be sprinkled, and is fitted with cut-out valves in each magazine, operated at valve and on berth deck in deck plates. It is connected with the fire system which serves the flooding system on upper platform, all of which is shown on the plans of the sprinkling system for the forward and after magazines.

All valves are brass gate valves.

FRESH AND SALT-WATER SYSTEMS.

The following is a general description of the fresh and salt-water systems :

Fresh-water Systems.—From the distiller pump the fresh water is discharged to the ripening tanks in after hold, or may be discharged, through a valve with lock, into the tanks forward. From the ripening tanks the water is pumped to the ship's tanks on the upper platform forward by the electric pump aft, and from these tanks may be pumped through the distributing main into the reservoir tanks on upper deck by the forward electric pump. All spaces are supplied with fresh

water from the reservoir tanks by gravity. In case the gravity tanks are out of commission, the forward and after electric pumps are arranged to run continuously, the surplus water being returned to the suction through relief valves in the discharge pipes. The wash rooms for machinists and petty officers, firemen and servants and the laundry are fitted with storage tanks, from which the fixtures are supplied. Other spaces are supplied directly from the main or branches.

For filling the ship's tanks from a dock or water boat, filling pipes are installed between frames 32–33 and 66–67, each fitted with a by-pass to the fresh water main.

Salt-water System.—The sanitary or flushing main is supplied by a direct connection from the distiller circulating pump and a by-pass from the fire system. All plumbing spaces aft of armor bulkhead 28 are supplied by this main.

The spaces forward of armor bulkhead 28 are served by an independent system, supplied by motor-driven certrifugal pumps, which draw from an independent sea valve. This system is also fitted with a by-pass from the fire system.

Deck Drains.—The officers' showers and baths, and firemen's and servants' wash rooms on gun deck, are drained through 4-inch pipes led under gun-deck beams, port side near center line, and discharging overboard through ship's scuppers, frame 42–43, and a special scupper, frame 70–71, port and starboard.

All other plumbing spaces are fitted with independent drains, with the exception of galleys and general mess pantry, which drain through ship's scupper, frame 42–43, port and starboard. The crew's showers on gun deck drain into ship's scupper, frame 9–10, port side only.

HEATING SYSTEM.

The heating system is divided into two sections, one forward and one aft, the forward section being divided into five radiator circuits, two galley and pantry circuits and one laundry circuit; the after section being divided into six radi-

ator circuits and two bath and shower circuits. Steam for radiators is supplied from the auxiliary steam line, the connection at the line being fitted with pressure gauges, stop and relief valves and reducing valves, set at 30 pounds. From this point the steam is carried to distributing manifolds and divided into circuits, as mentioned above, each circuit being arranged with a stop valve so that it can be operated independently of the others.

The galley and the pantry circuits also receive steam from the auxiliary steam line and are fitted with valves and gauges as on radiator lines, but are entirely independent, being constantly under steam. Steam for the laundry is taken from the evaporator shells.

The circuits supply steam to bakery, galleys, pantries, water heaters in bath and wash rooms, and also a coil located in fresh-water tanks to prevent water from freezing.

The drains from radiators are also divided into circuits and lead to receiving manifolds, located forward and aft, each circuit being arranged with a check and stop valve to prevent water from one circuit backing up into another. The discharges from manifolds lead to traps in engine rooms, each manifold having an independent trap, and the drains from these traps are connected together and lead to a drain manifold. This manifold discharges directly to filter tank with a branch on the line located so that it can also discharge to a manifold with branches leading either to the main or auxiliary condensers.

The drains from galleys and pantries lead directly to traps in engine rooms, each section being provided with an independent trap, and these traps discharge to drain manifold mentioned above. The drains from water heaters in bath rooms have no connection whatever with other drains and are carried directly to the auxiliary exhaust lines.

The circuit steam and drain pipes consist of seamless-drawn brass pipe, iron-pipe size, all pipes up to 1½ inches being connected together by composition fittings, but above that size

composition flanges are used. Connections at watertight bulkheads are made with composition stuffing boxes, and copper U-bends are installed throughout the lines to provide for expansion.

Particular care has been taken to prevent water hammer, and as all drains lead downward no pockets have been formed.

The radiators consist of coils made up of 1-inch seamless drawn-brass pipe, iron-pipe size, and composition fittings, stop and air valves.

The stop valves have stems of triangular cross section, valve-stem guards, socket keys for opening and closing, except radiators in officers' quarters, which are fitted with hand wheels. Unions are provided on outlet end of valves, so that radiators can be taken down without disturbing the lines.

Large radiators are divided into sections, each section having an independent steam and drain valve, so that in mild weather it is not necessary to have steam on the entire radiator.

ASH HOISTS.

The ash-hoist engines were designed and built by the Hyde Windlass Company. They are located in the upper hatches, the ventilator trunks containing the bucket guides, ropes and sheaves, etc. The hoist may be operated from either the main or upper decks and are designed to hoist to the upper deck, the bucket-guide rails extending from the bottom of the ventilator trunk to a point well above the upper deck, with trolleys at this deck for delivering ashes to the chutes at the ship's side. On the test 300 pounds were hoisted from the fireroom floor to the upper deck in five seconds, including starting and stopping, with 100 pounds steam pressure.

The hoisting engines are of the reciprocating type, with a rope drum, fitted with a follow-up and reversing gear, and an adjustable safety gear to prevent overwinding and stop the engine when the ash bucket reaches the fireroom floor.

DATA FOR ONE ENGINE.

Number of cylinders	2
Diameter of cylinder, inches	$4\frac{1}{2}$
Stroke, inches	$4\frac{1}{2}$
Diameter of drum, inches	10
Number of ash-hoist engines in ship	6

FORCED-DRAFT BLOWER.

The forced-draft blowers are located in the firerooms, being suspended from the protective deck about over the center of the stokehold. The engines and fans were designed and built by the B. F. Sturtevant Company.

The arrangement is the same for all of the firerooms, there being one engine, each driving two fans, located athwartship, so that the air is discharged directly to the stokehold floor at a distance of about two feet from the front of the boilers. The supply is taken from the fireroom ventilator ducts, which are closed at the bottom when under forced draft.

DATA FOR ONE BLOWER ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	6
Stroke, inches	6
Diameter of valve, inches	$3\frac{1}{4}$
Valve travel, inches	$2\frac{1}{2}$
Diameter of piston rods, inches	$1\frac{5}{16}$
crank shaft, inches	$3\frac{5}{16}$
pins, inches	$3\frac{1}{4}$
fan shaft, inches	$3\frac{3}{16}$
Length of connecting rod between centers, inches	$15\frac{3}{4}$
Number of bearings	5
Total length of bearings, inches	45
Crank angle, degrees	180

DATA FOR ONE BLOWER FAN.

Diameter of fan, inches	66
Number of blades	8
Width of tip of blades, inches	16
Area of induction nozzle, square inches	1,383
eduction nozzle, square inches	2,765

DATA FROM OFFICIAL TRIAL.

Average revolutions per minute	227.4
air pressure in firerooms	.49
I.H.P. for one blower	7
six blowers	42

MACHINE SHOP.

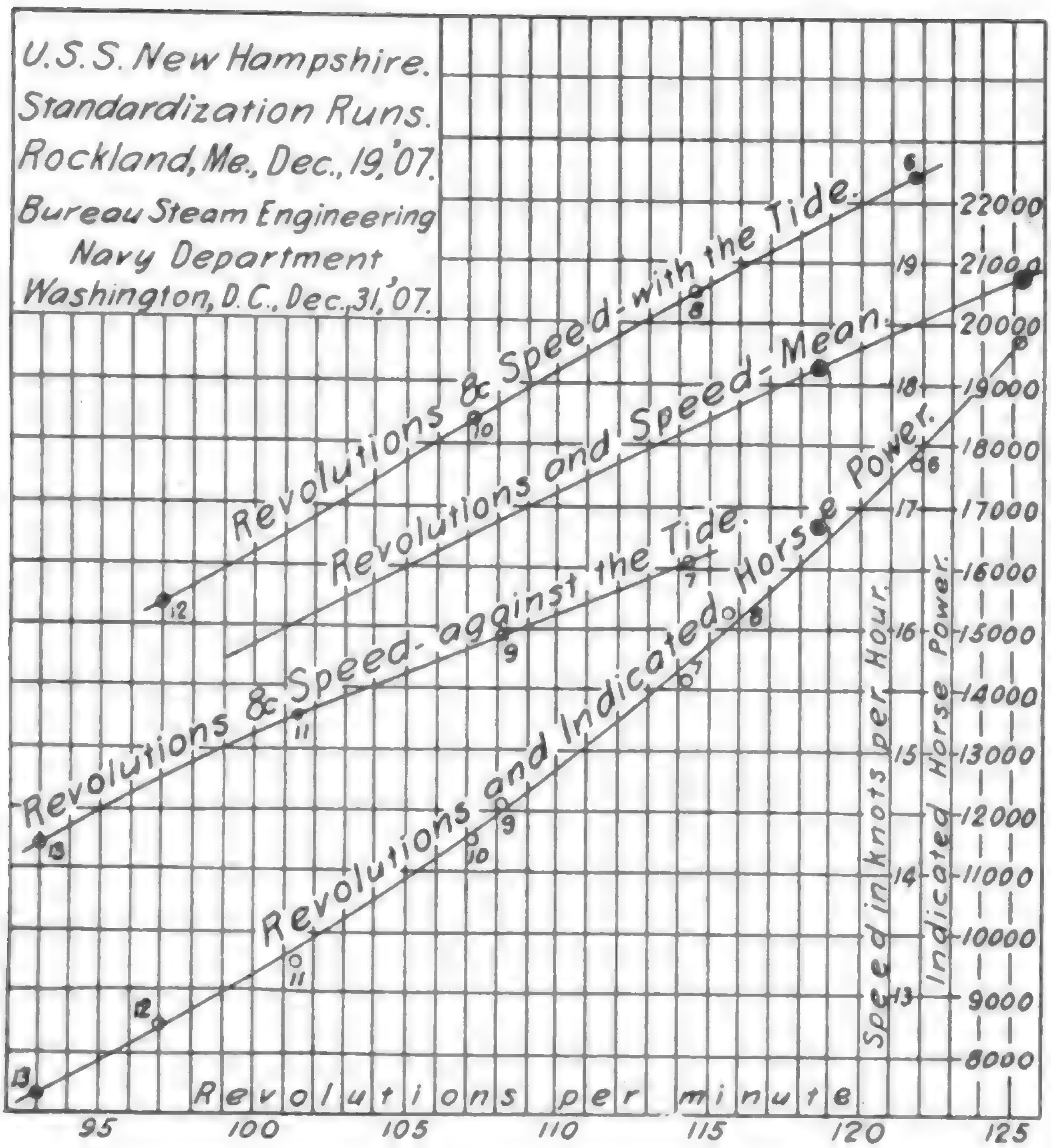
The machine shop is located amidships on the berth deck forward of the after 12-inch barbette and between the machinery hatches, access to it being from the athwartship passage and from the engine rooms through their respective entrance hatches. The machines are arranged with line and counter shaft driven by a 15-horsepower General Electric motor. On a test made to determine whether the motor was sufficiently powerful to do the work, with all machines working on hard cast iron at a heavy cut, 6.21 horsepower was developed.

The following machines are installed:

1 28-inch extension gap lathe;
1 14-inch engine lathe;
1 16-inch crank shaper;
1 31-inch radial-drill press;
1 16-inch sensitive-drill press;
1 30-inch grindstone;
1 Universal milling machine;
1 12-inch emery grinder;
1 combined hand punch and shears;
6 bench vises.

The tools are provided with the most modern attachments, including scroll and drill chucks, index head, automatic cross feed, swivel table, pipe vises, etc., and all necessary tools, drills and cutters.

NOTE.—The writer wishes to acknowledge the receipt of valuable assistance from Mr. Eskel Berg, of the General Electric Company, in the preparation of that part of this article pertaining to the electric plant; and to Mr. J. F. Hunnewell, chief draftsman in the office of the Superintending Constructor at these works, for the description of the pumping and drainage system.


U.S.S. New Hampshire.
Standardization Runs.
Rockland, Me., Dec., 19, '07.
Bureau Steam Engineering
Navy Department
Washington, D.C., Dec. 31, '07.
Revolutions & Speed-with the Tide.
Revolutions and Speed-Mean.
Revolutions & Speed-against the Tide.
Revolutions and Indicated Horse Power.
Speed in knots per Hour.
Indicated Horse Power.
Revolutions per minute
95
100
105
110
115
120
125
13
14
15
16
17
18
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8000
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10000
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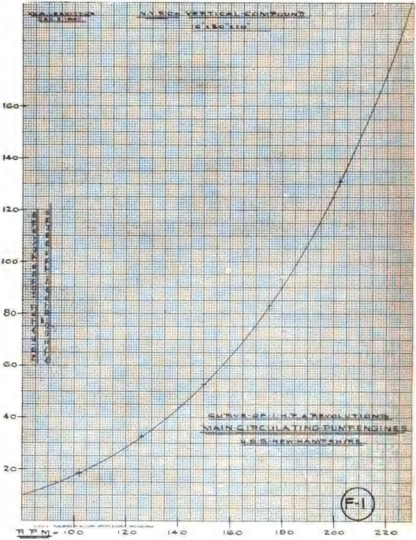
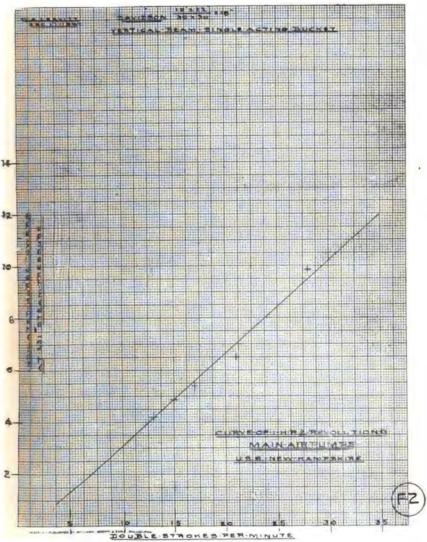
19000
20000
21000
22000

Plate I.


N.Y.S.Co. VERTICAL COMPOUND
10"x20"x10"
INDICATED HORSE POWERS
AT 100# STEAM PRESSURE
160
140
120
100
80
60
40
20
CURVE OF I.H.P. & REVOLUTIONS
MAIN CIRCULATING PUMP ENGINES
U.S.S. NEW HAMPSHIRE
F-1
R.P.M. - 100
120
140
160
180
200
220


VERTICAL BEAM, SINGLE ACTING BUCKET
CURVE OF I.H.P. & REVOLUTIONS
MAIN AIR PUMPS
U.S.S. NEW HAMPSHIRE
DOUBLE-STROKES-PER-MINUTE
2
4
6
8
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12
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25
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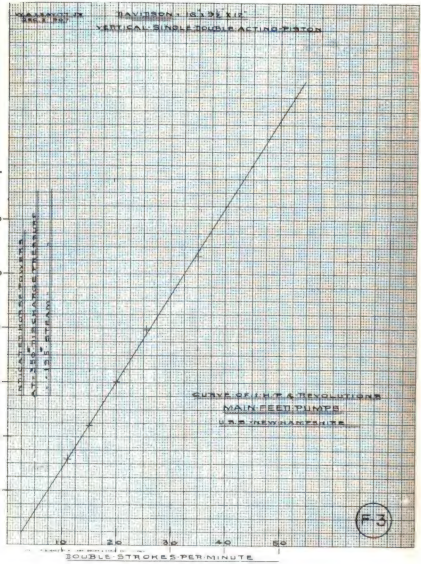
35
FZ


DAVIDSON · 16" x 9½" x 12"
VERTICAL · SINGLE DOUBLE ACTING · PISTON
INDICATED HORSE POWERS
AT 350# DISCHARGE PRESSURE
& 125# STEAM
CURVE OF I.H.P. & REVOLUTIONS
MAIN FEED PUMPS
U.S.S. NEW HAMPSHIRE
60
50
40
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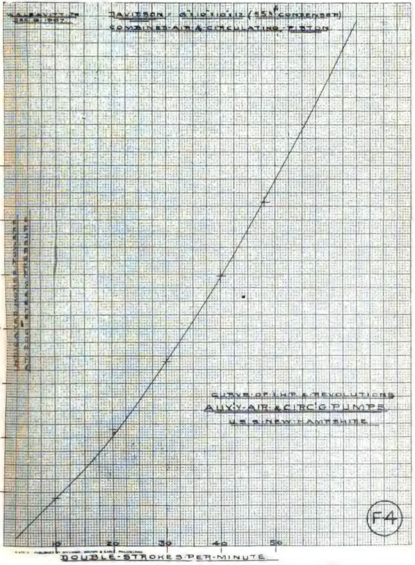
50
DOUBLE · STROKES · PER · MINUTE
F-3


DAVIDSON
COMBINED AIR & CIRCULATING PISTON
CURVE OF I.H.P. & REVOLUTIONS
AUX'Y AIR & CIRC'G PUMPS
U.S.S. NEW HAMPSHIRE
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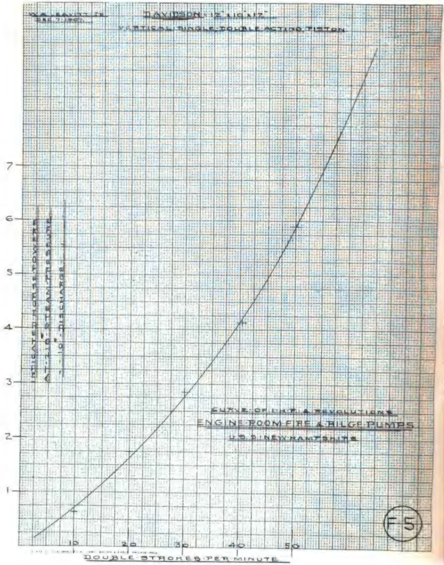
DOUBLE-STROKES-PER-MINUTE
F4


W. A. LEAVITT JR
DEC. 7, 1907.
DAVIDSON 12" x 10" x 12"
VERTICAL SINGLE DOUBLE ACTING PISTON
INDICATED HORSE POWER
AT 110" STEAM PRESSURE
" 10" DISCHARGE
CURVE OF I.H.P. & REVOLUTIONS
ENGINE ROOM FIRE & BILGE PUMPS
U.S.S. NEW HAMPSHIRE
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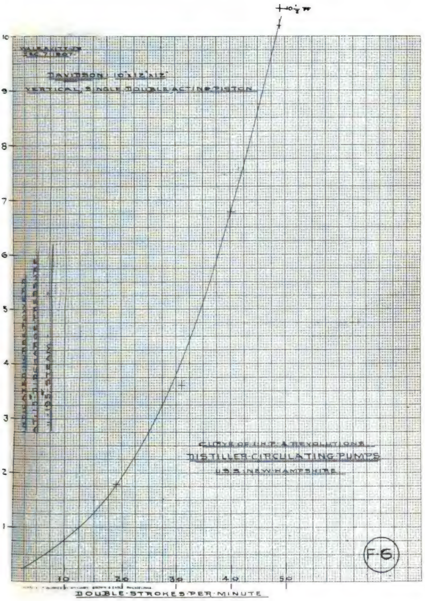
DOUBLE STROKES PER MINUTE
F 5


+10½ ᴴᴾ
DEC. 7 1907
DAVIDSON 10"x12"x12"
VERTICAL SINGLE DOUBLE ACTING PISTON
INDICATED HORSE POWER
AT 15# DISCHARGE PRESSURE
& 105# STEAM
CURVE OF I.H.P. & REVOLUTIONS
DISTILLER CIRCULATING PUMPS
U.S.S. NEW HAMPSHIRE
F-6
1
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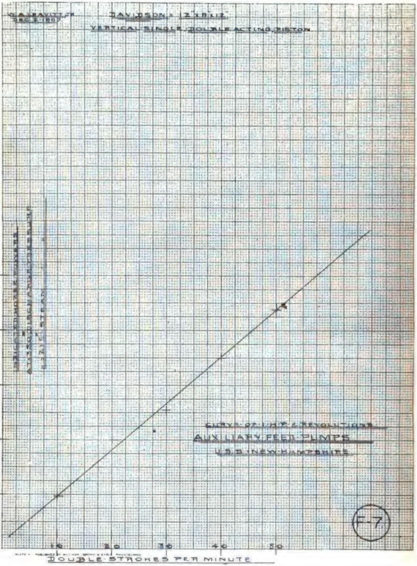
50
DOUBLE-STROKES-PER-MINUTE


W. A. LEAVITT JR
DEC 2 1907
DAVIDSON 12" x 8" x 12"
VERTICAL SINGLE DOUBLE ACTING PISTON
INDICATED HORSE POWERS
AT 350 DISCHARGE PRESSURE
& 215 STEAM
50
40
30
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10
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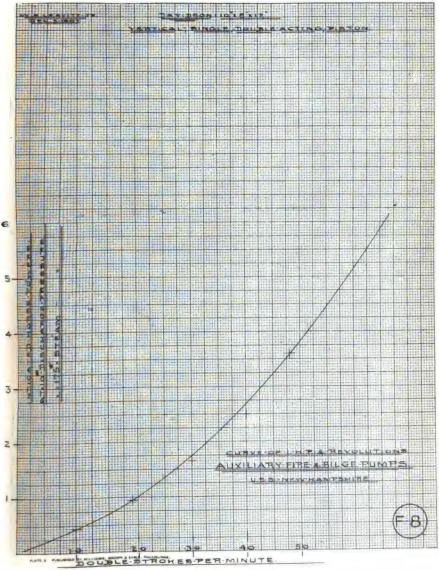
DOUBLE STROKES PER MINUTE
CURVE OF I.H.P. & REVOLUTIONS
AUXILIARY FEED PUMPS
U.S.S. NEW HAMPSHIRE
F-7


DAVIDSON 10"x 6"x 12"
VERTICAL, SINGLE, DOUBLE ACTING, PISTON.
INDICATED HORSE POWER
AT 100# DISCHARGE PRESSURE
& 125# STEAM
6
5
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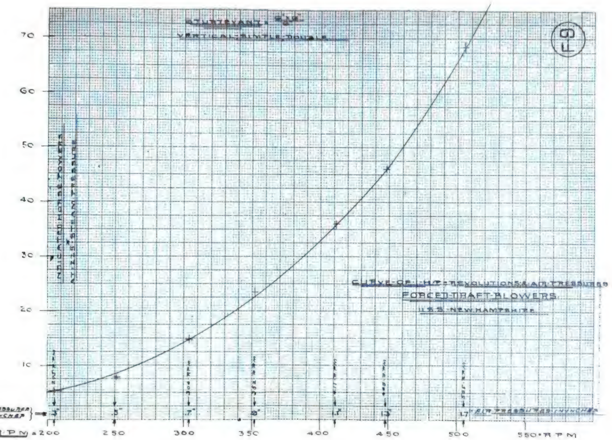
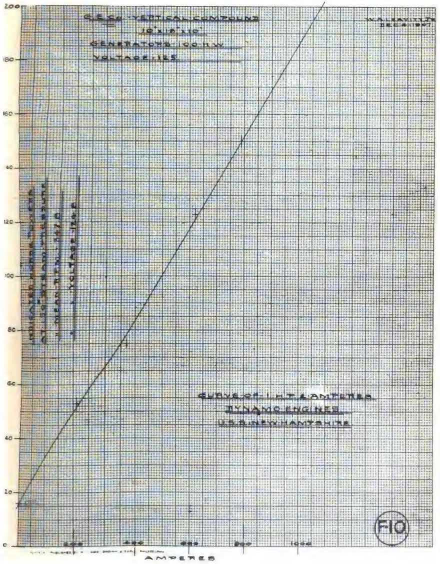
CURVE OF I.H.P. & REVOLUTIONS
AUXILIARY FIRE & BILGE PUMPS
U.S.S. NEW HAMPSHIRE
F-8
DOUBLE-STROKES-PER-MINUTE

STURTEVANT
VERTICAL SIMPLE DOUBLE
INDICATED HORSE POWERS AT 225 STEAM PRESSURE
CURVE OF I.H.P. - REVOLUTIONS & AIR PRESSURES
FORCED DRAFT BLOWERS
U.S.S. NEW HAMPSHIRE
F9
10
20
30
40
50
60
70
AIR PRESSURES IN INCHES
R.P.M. = 200
250
300
350
400
450
500
550 R.P.M.
205 R.P.M.
304 R.P.M.
352 R.P.M.
411 R.P.M.
448 R.P.M.
505 R.P.M.
.3"
.5"
.7"
.9"
1.1"
1.3"
1.7"
AIR PRESSURES INCHES


G.E.CO. VERTICAL COMPOUND
10"x18"x10"
GENERATORS 100 K.W.
VOLTAGE 125
W. A. LEAVITT
DEC. 4. 1907
INDICATED HORSE POWER
AT 110 LBS. STEAM PRESSURE
MEAN R.P.M. 347.0
VOLTAGE 124.8
CURVE OF I.H.P. & AMPERES
DYNAMO ENGINES
U.S.S. NEW HAMPSHIRE
FIG
0
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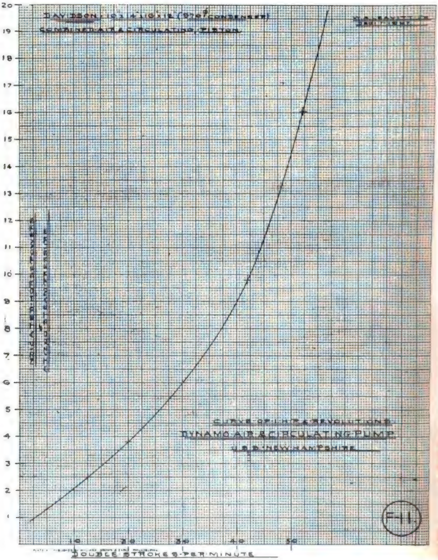
800
1000
AMPERES


DAVIDSON: 10 1/2 × 10 × 12 (5700 CONDENSER)
COMBINED AIR & CIRCULATING PISTON
CURVE OF I.H.P. & REVOLUTIONS
DYNAMO AIR & CIRCULATING PUMP
U.S.S. NEW HAMPSHIRE
INDICATED HORSE POWER
AT STEAM PRESSURE
DOUBLE STROKES PER MINUTE
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19
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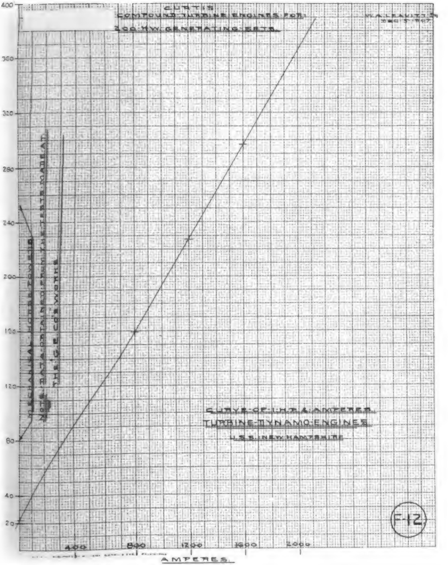
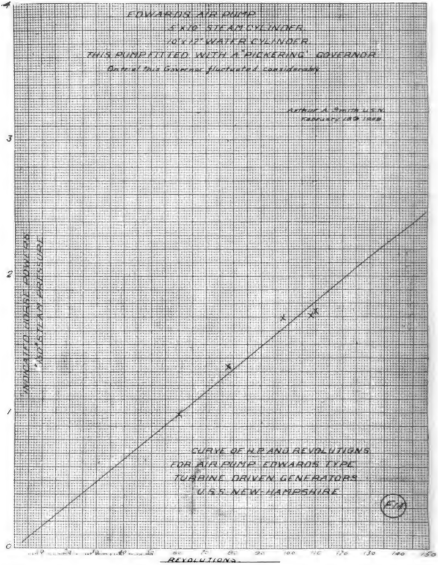
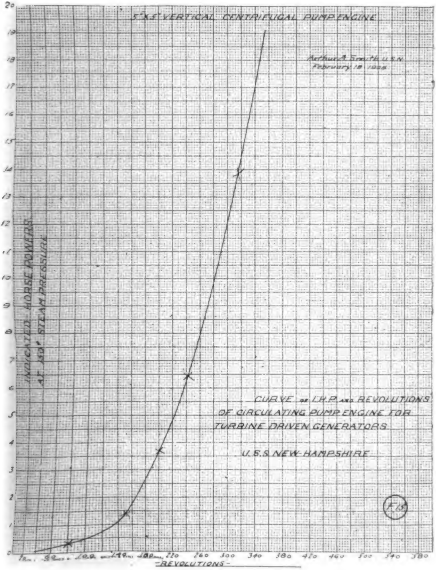
6
5
4
3
2
1
10
20
30
40
50

F-11.


CURTIS
COMPOUND TURBINE ENGINES FOR
200 KW. GENERATING SETS.
W. A. LEAVITT Jr.
DEC 5 1907
MECHANICAL HORSE POWERS
NOTE. DATA OBTAINED FROM THE TESTS MADE AT
THE G. E. CO'S WORKS
CURVE OF I.H.P. & AMPERES.
TURBINE-DYNAMO-ENGINES
U.S.S. NEW HAMPSHIRE
F-12
400
360
320
280
240
200
160
120
80
40
20
400
800
1200
1600
2000
AMPERES.


EDWARDS AIR PUMP
5"x10" STEAM CYLINDER.
10"x12" WATER CYLINDER.
THIS PUMP FITTED WITH A "PICKERING" GOVERNOR
On trial this Governor fluctuated considerably
Arthur A. Smith U.S.N.
February 18th 1909
INDICATED HORSE POWERS
180# STEAM PRESSURE
CURVE OF H.P. AND REVOLUTIONS
FOR AIR PUMP EDWARDS TYPE
TURBINE DRIVEN GENERATORS
U.S.S. NEW HAMPSHIRE
F.H.
4
3
2
1
0
60
70
80
90
100
110
120
130
140
150
REVOLUTIONS.


5"X5" VERTICAL CENTRIFUGAL PUMP ENGINE
Arthur A Smith U.S.N.
February 18 1908
INDICATED HORSE POWERS
AT 150# STEAM PRESSURE
CURVE OF I.H.P. AND REVOLUTIONS
OF CIRCULATING PUMP ENGINE FOR
TURBINE DRIVEN GENERATORS
U.S.S NEW-HAMPSHIRE
F15
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
220
260
300
340
380
420
460
500
540
580
-REVOLUTIONS-

SPECIFICATIONS FOR STEAM COAL.

By Civil Engineer A. C. Cunningham, U. S. Navy, Member.

Of all the raw materials extensively and continuously used in the United States, by both the Government and private establishments, probably none have had less supervision and limitation by the consumer than steam coal. Ores of various kinds, lumber, and even sand and gravel are bought under various requirements and limitations, but until practically the present time coal was coal, good, bad or indifferent. It has been bought and used on its reputation, or the reputation and representation of coal dealers, and the consumer has gone placidly on, generally contented, or, when sufficiently discontented, with a change of dealers.

A brief consideration explains this condition. Most raw materials pass into a finished product the quality of which depends upon the quality of the raw material. Steam coal passes into smoke and cinder, and in so doing develops heat. If enough heat is produced to satisfy the consumer, and not too much ash, cinder and clinker to cause him undue trouble and expense, all is well. The most coal he has ever used is his standard; if he keeps inside that amount he is satisfied. The great bulk of coal is used by consumers who naturally have no technical knowledge of the same nor any convenient means of having its quality and value tested. To them "B. T. U." is in the same class as moment of inertia, specific heat, integral signs and the many other things that we use to mystify the ordinary man who has not had the opportunity to dig as deeply into books as some of us.

This condition of buying steam coal on its reputation or

the representation of dealers has begun to change. Many prominent civil concerns have adopted specifications governing the quality of the coal which they purchase, and the Government, through the Geological Survey, is beginning to follow their practice. The intricacies and complications of some of these specifications are interesting, or even amusing, and seem to show a strong influence on the part of the dealer to have the same old coal go as usual. Every one using coal knows that rejections and cancellation of contracts are practically impossible if it is desired to continue business and not shut down a plant for an indefinite period. The coal dealer knows this quite as well as the consumer. In consequence of this condition the important specifications that have been so far used set a standard for the coal that is desired, and then provide a bonus for coal which is better and a fine for that which is poorer. Even the specification of the Geological Survey shares this defect.

Why this bonus and fine in a specification is a defect is as follows: If a steam plant is to produce definite and uniform results a certain minimum quality of coal is necessary to do it; the more nearly a steam plant is worked up to its rated capacity the more apparent does this become; the more nearly it is worked up to its possible capacity the more absolutely certain does it become. Now, if the average quality that is specified is the minimum that is necessary for a plant that is worked up to its rated, or even its possible, capacity, then with any quality below this the plant will not do the necessary work, and everything depending on it will suffer accordingly.

Experience has demonstrated that it will not do to specify the minimum quality of coal that will satisfactorily operate a plant if it is possible for the dealer to furnish anything poorer. It may be necessary or desirable for him to sometimes furnish such poorer coal, and the penalty portion of a specification is very necessary and desirable to encourage him to keep up to the standard established.

Why the bonus portion of a coal specification is a defect is

as follows: In no class of raw material, or material which is to be re-worked, is an average quality specified. A minimum quality is set, and it is safe to leave it to the dealer that nothing much better than this will be furnished. This is true of ores, lumber, cement, iron and steel, provisions and everything that can be readily named. The reason for this minimum quality in re-worked material is apparent, for if it were not for this rule some parts of the finished product would be poorer than others, as in a boiler, a building or a line of pipe, and we are brought to the condition which has produced the maxim that "the strength of a chain is the strength of its weakest link." Why we endure an average quality in a coal specification is due to several reasons. Coal specifications are new, and we have used and endured an average quality for very many years; the coal dealer has some influence and weight with us in his trouble; we do not turn the coal into a finished product, and there are no apparent or enduring results from using an average, or partly good and partly poor coal. Thus when we allow a bonus on coal we are not improving the quality except by paying extra for it, and even then the improvement of quality is at the mercy of the dealer and not the consumer.

When detailed to duty at the Norfolk Navy Yard, the author was confronted by a "condition and not a theory" on the question of steam coal. This yard has always been a natural market for Pocahontas coal, and such had been specified without further qualification. Keen competition, however, succeeded in eliminating "Pocahontas" from the specification and substituting definite requirements for the constituents of the coal. A foreign coal took the contract and trouble immediately began. The requirements for the coal were not met, and as the specification provided for no penalty, the steam plant became "the sport of circumstances." The contract was finally canceled and relet under an improved specification containing a penalty provision. The contract was taken by the same parties who furnished the unsatisfactory coal at an advance of only seven cents a ton,

and coal equal to the average of Pocahontas was thereafter supplied. This experience led to a considerable study of the coal question and how to control it, and it is believed that the following specification is simple, reasonable and just; that it will produce a fair competition and restrain the bidder from offering goods that he cannot deliver.

The limitations in the specification are liberal for such coal as would naturally reach the Norfolk market, and the general quality is not the lowest that could be used under usual conditions; occasional failure on the part of the contractor would not produce serious conditions, and the extra labor and coal, due to a failure, would be compensated for.

SPECIFICATION FOR COAL.

(1.) Coal shall be of steaming quality, bituminous or semi-bituminous, run of mine, and as free from deleterious and objectionable matter as consistent with the best mining and transportation practice.

(2.) Payment shall be made on the weight of coal as delivered to the consumer.

(3.) Representative samples, selected from the coal as delivered to the consumer, shall, on laboratory test, not exceed the following limits of the substances named:

Moisture, per cent.	1
Volatile matter, per cent.	22
Sulphur, per cent.	1
Ash and solid matter, per cent.	7

(4.) Bidders shall state in their proposals the least calorific value of the coal they propose to furnish, when dried, in British thermal units per pound of coal. The calorific value named in the accepted proposal shall form part of the contract, and tests will be made for same on dried coal from representative samples of the coal as delivered. Coal falling short in calorific value of the standard established by the accepted bid shall be reduced proportionately in price.

(5.) For each one whole per cent. of moisture on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(6.) For each one whole per cent. of ash and solid matter on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(7.) For each whole half per cent. of sulphur on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(8.) For each one whole per cent. resulting from the addition of the excesses of moisture, sulphur, ash and solid matter, or any two of them, when below the deduction limits named for each separately, on laboratory test, there shall be deducted 1 cent per ton from the contract price of the coal.

(9.) Tests for calorific value shall be made with a bomb calorimeter, and all laboratory tests in accordance with the latest approved methods of the American Chemical Society.

(10.) The contractor, or his authorized representative, may have the privilege of witnessing the weighing, sampling and analysis of coal, provided that no undue delay is caused thereby, or the user may have the same verified by a competent and responsible person; but in any event the weighing, sampling and analysis made upon the delivery of coal shall be final.

(11.) Failure of the coal to comply with the specified requirements and original limitations shall be sufficient cause for rejection or cancellation of the contract.

The foregoing specification is the outcome of the author's endeavor to secure good steaming coal, the result of the study of available literature and specifications and the observation of the working of coal in connection with its analysis. A translation of the specification will be next in order:

Steam coal may be anthracite, semi-bituminous, bituminous or peaty in its nature; local conditions and available supply will determine which is used, but bituminous and semi-bituminous are by far the most largely and widely used, and the actual difference between them is sometimes small. "Run

of mine" coal is generally accepted to mean coal that contains not less than forty per cent. of lump, no lump of less dimensions than a three-inch cube. Coal may leave the mine in this proportion, but in successive handlings may become so broken up as to generally resemble "slack" in fineness. It has not, however, lost any of its original quality, and if it passes all tests and fires satisfactorily no exceptions need be taken to the proportion of lump, which is hard to ascertain at the best.

Other classifications of coal are as follows: "Lump," in which not over ten per cent. is of a size the equivalent of a three-inch cube, and the balance greater; "Egg" or "Nut," in which not over ten per cent. is of a size equivalent to a one-and-a-quarter-inch cube, and the balance in larger sizes, but not exceeding the equivalent of a three-inch cube; "Steam Nut," in which not over ten per cent. is of a size equivalent to a half-inch cube, and the balance in larger sizes but not exceeding the equivalent of a one-and-a-quarter-inch cube; "Slack," which is everything under the equivalent of a half-inch cube, including dust, slate, dirt and any other objectionable or deleterious matter that may be present.

These classifications are not universal or rigid; they are applied to the coal at the mine, and subsequent handling and transportation may produce conditions which are intermediate to the original ones, and also more or less fine coal, sometimes wrongfully called "slack." From a consideration of these classifications it will be obvious that "run of mine" will be the cheapest coal of good quality for general steaming purposes.

The principal objectionable and deleterious matters that occur in coal are the various natural combinations of sulphur, slate, crop coal, white scale and bone coal. Crop coal is that part of the vein that has been exposed to the weather. White scale is carbonate of lime and an adulterant. Bone coal is a portion of the vein that is intimately mixed with fine slate or clay. All deleterious and objectionable matters are fairly visible to a trained eye and should be separated from the coal at the mine.

The weight of coal as delivered to the user will vary with the amount of moisture it has given up or absorbed from the time it has been mined until it is delivered. It may come from the mine wet and drain out or dry in transportation, or it may come from the mine dry and absorb moisture from exposure to rain and snow in transit. In well-handled and transported coal the moisture will usually vary from one-half of one per cent. to one per cent. In a test on a twenty-pound sample the author found that about five per cent. of moisture could be carried without dripping. It is necessary to limit the amount of moisture that will be accepted, in order to insure careful handling and transportation. It is sometimes thought that moisture improves the burning and heating value of coal; for those who think so it is better to add the moisture and not pay from three to five dollars a ton for it. It seems hardly necessary to say that moisture not only has no heating value, but uses up a certain amount of otherwise effective coal in evaporating it.

A representative sample selected from the coal as delivered should contain as nearly as possible the same proportion of lump, fine coal and dirt as the shipment. By selecting from various depths it may also be taken so as to contain about the average percentage of moisture. Analyses made on lump coal only will show very much better results than an average sample, and analyses made on fine coal only will give poorer results than the average. The reason is obvious, as the lump coal comes from the purest and most solid part of the vein, and is largely free from slate, dirt and sulphur compounds. The fine coal, on the contrary, is mixed with the deleterious and objectionable substances. Many specifications give elaborate directions for pulverizing, quartering and re-quartering the sample for analysis. It is important that the sample should be representative of the general and average condition of the coal, and that it should be placed in fairly tight receptacle to prevent the evaporation or absorption of moisture; these precautions being taken, the chemist can be depended upon for further details.

The volatile matter in coal is generally and principally hydrogen, oxygen and nitrogen, and in proportions of from 15 to 20 per cent.; the approximate relation of these elements is about 5 hydrogen, 4 oxygen and 1 nitrogen. The volatile matter has no practical heating value.

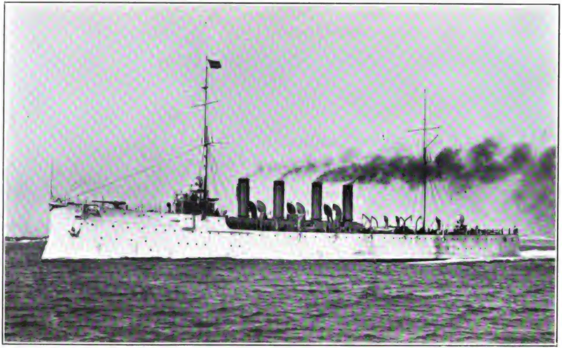
Sulphur has two general effects on coal, and the less there is of it the better will be the general results. The tendency to spontaneous combustion is directly proportional to the sulphur content, and the greater the mass in which coal is to be stored and the longer it is to be kept in storage the less should be the sulphur contained. For coal that is to be stored in large masses for a long time, the best results will be had from "lump coal" instead of "run of mine." Lump coal is naturally the purest and most free from sulphur. It will have considerable ventilation as against none in "run of mine;" it will drain off water readily instead of holding it to produce slow chemical action. The other general effect of sulphur is to form clinker. It is a safe general proposition that the higher the sulphur the higher will be the ash, slate and other inert matter, and under the effects of heat clinkers will form which will kill the draft and more or less injure grate bars and brick linings.

The ash and solid matter shown by analysis will increase in per cent. in actual firing. The smaller the ash shown on analysis the less will be the proportional increase in firing, and the greater the ash on analysis the greater will be the proportional increase in firing. It is claimed that with an ash content of 40 per cent. the evaporative power of coal becomes zero, and this might easily prove to be the case. With low ash the least stoking is required and, consequently, the least opening of furnace doors and cooling effect of excess of air. With high ash much stoking is required, and there results not only the cooling effects of excess of air, but a waste of coal itself from the necessary slicing and overturning of the fire. When high sulphur and high ash produce excessive clinkering, fires must be worked constantly to produce any results at all, and at the best they will be poor.

The calorific value of the steam coals available on the Atlantic Coast will vary between 13,000 and 15,000 British thermal units, and in general be at about 14,000 units, this unit being the amount of heat necessary to increase the temperature of a pound of water by one degree Fahrenheit. The heating value of coal is the first consideration, and varies in general with its analysis. To require the contractor to name the heating value places him "between the devil and the deep sea." The higher he sets it in his bid the more likely is he to get the contract, and if he sets it higher than he can meet he is subject to fines for which he has taken the responsibility in advance. The general result is to produce close competition and a true representation of the coal. The calorific value is determined on dried coal, so that there may be no complications due to varying amounts of moisture at different times.

The calorific value may be set so low that excesses of moisture, sulphur and ash over the specified requirements are possible, and, as these substances affect the practical burning of the coal, a fine is also set for excesses that will keep them within practical bounds.

It is believed that this specification is practical, just and equitable, and will tend to fair competition. If desirable, it may be further modified by asking bidders to set the limits for the substances named where greatly varying coal is likely to be encountered and limited quality is of no great importance.



U. S. S. "Chester."

DESCRIPTION AND TRIALS OF U. S. S. *CHESTER*.

BY LIEUTENANT A. F. H. YATES, U. S. N., MEMBER.

The *Chester* is one of three scout cruisers authorized by an Act of Congress, approved April 24th, 1904. Owing to the rapid development of the steam turbine for marine use, the Navy Department decided to contract for these three vessels to be exactly similar but for their propelling machinery. The contract for the *Chester* was made with the Bath Iron Works, Limited, of Bath, Me., on the 4th of May, 1905, and called for her completion and delivery to the Government on or before the expiration of thirty-six months from the above date. The propelling machinery of the *Chester* consists of Parsons marine steam turbines, driving four independent shafts, each shaft being fitted with one propeller, and cruising turbines fitted to give economy at low power. Exclusive of the cruising turbines there are two main high-pressure turbines exhausting into two low-pressure turbines, and in each of the latter there is incorporated a reversing turbine. To obtain economy at low and moderate speeds the six turbines may be used in three combinations:

First, for low speeds—up to about 18 knots.—The steam passes through all six ahead turbines, both the H.P. cruising and the I.P. cruising being connected up with the four main turbines. Steam admitted to the H.P. cruising exhausts into the I.P. cruising, and from the latter exhausts through separate pipes to each of the main H.P. turbines. From these latter it exhausts into the L.P. turbines and then into the main condensers.

Second, for moderate speeds—up to about 23 knots.—The steam passes through five ahead turbines, steam being admitted

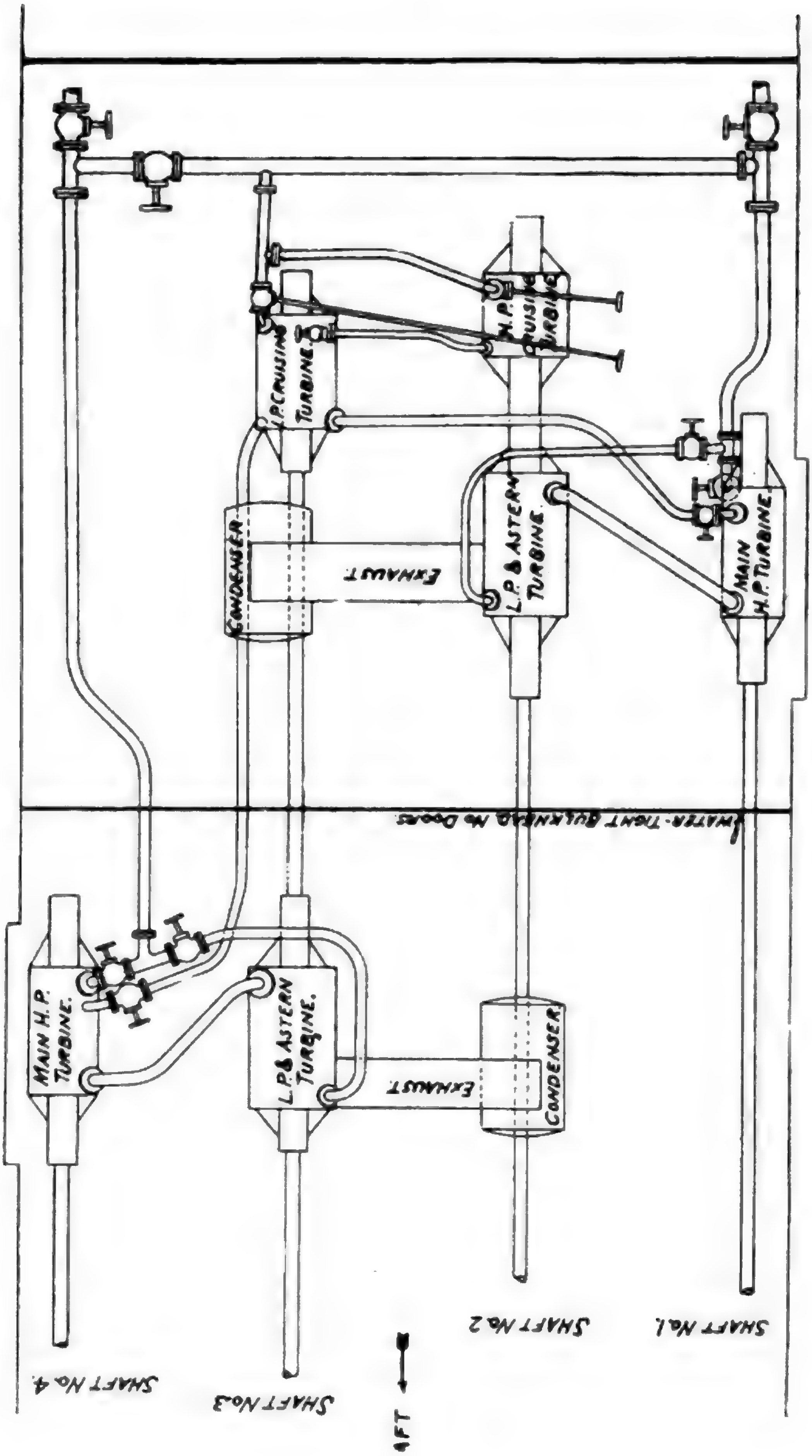

H.P. CRUISING TURBINE.
H.P. CRUISING TURBINE
MAIN H.P. TURBINE
L.P. & ASTERN TURBINE.
CONDENSER
EXHAUST
WATER-TIGHT BULKHEAD No Doors
MAIN H.P. TURBINE.
L.P. & ASTERN TURBINE.
EXHAUST
CONDENSER
SHAFT No. 4.
SHAFT No. 3
SHAFT No. 2
SHAFT No. 1.
AFT

FIGURE 1

to the I.P. cruising turbine and passing thence to the two main high-pressure turbines, and from each of them to the connected low-pressure turbine. The high-pressure cruising turbine revolves idly in a vacuum.

Third, for highest speeds.—Only the four main turbines are used, steam being admitted to each main H.P. turbine. Both cruising turbines revolve idly in a vacuum.

For diagram of arrangement and piping see Figure 1.

Reduction of power in each of the arrangements is obtained by throttling. Increased power may be obtained by admitting live steam to the I.P. cruising turbine in the *first* arrangement and to the main H.P. turbine in the *second* arrangement. By-pass valves are fitted from the first to the second expansions in both main H.P., and auxiliary exhaust steam may be admitted to the second expansions in main H.P. turbines and to both L.P. receiver pipes.

The turbines were designed for a working pressure at the turbines of 250 pounds per square inch and to drive the shafts at 502 revolutions per minute for the contract speed of 24 knots.

The contracts for the other two vessels, the *Birmingham* and the *Salem*, were awarded the Fore River Shipbuilding Company, of Quincy, Mass., the *Birmingham* to be equipped with two vertical, inverted-cylinder, direct-acting, triple-expansion engines of Navy Department's design, and the *Salem* with two seven-stage, Curtis, reversible, marine steam turbines.

General hull data of the *Chester* are as follows:

HULL DATA.

Length between perpendiculars, feet	420
over all, feet and inches	423–02
on water line (16 feet 9.5 inches), feet	420
of straight keel, feet and inches	340–06
Beam, extreme, at 16 feet 9.5 inches W.L., feet and inches	47–01½
on main deck, feet and inches	40–05
Greatest beam, hull proper, situated at normal L.W.L., ft. and ins.	47–01½
Breadth, over all, feet and inches	47–01½
Draught, to top of keel, feet and inches	16-08⅜

Molded depth (from top of main-deck beam at side to bottom of frame at M. P.), feet and inches	36–05$\frac{5}{16}$
Keel projects below molded base line, inch	00$\frac{11}{16}$
Ratio of lengh to beam	8.97
immersed area of longitudinal section to rudder area	34.1
Number of screws	4
Outboard shafts, incline up and forward, angle, degrees	2.46
Inboard shafts, incline up and forward, angle, degrees	1.44
Shafts diverge at an angle with center line of ship, degrees	.72
Outboard shafts, center line at frame No. 78, from center line of ship, feet and inches	10–04
Inboard shafts, center line at frame No. 78, from center line of ship, feet and inches	3–06
Outboard shafts, center line at frame No. 78, from base line, feet and inches	15–10
Inboard shafts, center line at frame No. 78, from base line, feet	12
Outboard shafts, center line at frame No. 131, from center line of ship, feet and inches	12–04
Inboard shafts, center line at frame No. 131, from center line of ship, feet and inches	5–06
Outboard shafts, center line at frame No. 131, from base line, ft.	9
Inboard shafts, center line at frame No. 131, from base line, feet	8
Outboard shafts, rake up and forward per foot, inch	.52
Inboard shafts, rake up and forward per foot, inch	.31
Both shafts, rake outward per foot, inch	.15
Distance of center line of outboard screws forward of A.P., feet and inches	43–02$\frac{1}{4}$
Distance of center line of inboard screws forward of A.P., feet and inches	24–07$\frac{1}{2}$
Distance of center line of outboard screws from center line of ship, feet and inches	12–04
Distance of center line of inboard screws from center line of ship, feet and inches	5–06$\frac{31}{32}$
Strut centers for outboard shaft forward of A.P., feet	46
inboard shaft forward of A.P., feet	28

STEAMING TRIALS.

The wonderful results attained by the *Chester* during her trials far exceeded all expectations and established her as the fastest man-of-war in the world of over 1,500 tons displacement, and, indeed, as the fastest of all the world's large vessels.

The contract required a *progressive* trial over a measured mile course for the purpose of standardizing the screws, extending from maximum speed down to a speed of about 12

knots; a *full-speed* trial of four hours' duration in the open sea, guaranteed speed not to be less than an average of 24 knots per hour as determined by the standardization curve, air pressure not to exceed 5 inches of water, displacement with 475 tons of coal, etc., etc., on board, not to exceed 3,750 tons; two *endurance* and *coal-consumption* trials, each of 24 hours' duration, one to be run at an average uniform speed of about 12 knots under service conditions, and the other to be run at a uniform speed to average not less than 22.5 knots per hour under service conditions, displacement on each trial to average as on *full-speed* trial.

The date set for the beginning of these trials was February 27, 1908, and on February 13th the builders took the *Chester* to the Navy Yard at Charlestown, Mass., for drydocking. There her bottom was cleaned and painted, after which she returned to the works of the company at Bath. After leaving Bath for Charlestown the vessel was taken to Southport, Maine, for a private standardization, but, as the weather was unfavorable, no satisfactory results could be obtained. Both on the run to and from Charlestown the vessel was run at varying speeds to determine the general conditions of the machinery and to become acquainted with existing pressures, etc. On the run to Charlestown it was found that at high pressures on cruising turbines the gland system was not handling all of the gland leak-off steam from the H.P. and I.P. cruising turbines, and consequently an excessive amount of steam vapor found its way into the forward engine room. This was remedied upon arrival at Charlestown by installing a branch pipe from the forward section of gland equalizer piping to the starboard L.P. exhaust to condenser. On starting the port main H.P. turbine on one occasion a slight grinding noise was heard, and upon arrival at Charlestown the casing of this turbine was lifted and the blading examined. The casing blades, particularly in the second expansion, were found to be slightly distorted, and the binding wire broken in a few places. The blades were straightened, filed down somewhat, and soldered. There is no doubt but what this was due to heating the tur-

bine with auxiliary exhaust steam, when warming up before turning the turbine, admission of this steam being at that point, causing local and unequal expansion. This practice was discontinued, and no similar trouble experienced subsequently.

It should, perhaps, be remarked that, previous to the run to Charlestown, a dock trial of the machinery was held at the works. This trial was held on February 6, 1908, and lasted three hours, beginning at 11 A. M. and ending at 2 P. M. From 11 A. M. to meridian steam was admitted to the H.P. cruising turbine, all six turbines being in operation. The average revolutions of all shafts was 197.5. From meridian to 1 P. M. steam was shut off the H.P. cruising turbine and admitted to the I.P. cruising, the former running in a vacuum. Five turbines were then in operation. The average revolutions of all shafts was 191.5. From 1 P. M. to 2 P. M. steam was shut off the I.P. cruising turbine and admitted to both main H.P. turbines. Both cruising turbines then ran idle in a vacuum, the four main turbines being in operation. The average revolutions of all four shafts was 193.4. The machinery worked most satisfactorily throughout the trial. A short backing test concluded the trial. The data obtained, having little significance, is omitted from these papers.

On February 25 the *Chester* left Bath for Rockland, Me., arriving in a few hours. A private standardization trial was held by the builders upon arrival for the purpose of preparing for efficient management of the machinery on the occasion of the official standardization trials. On the 26th instant the Naval Board of Inspection and Survey arrived at Rockland and went on board. The weather being unfavorable upon the date set for the trial (February 27th), the latter was postponed until the next day.

OFFICIAL STANDARDIZATION TRIAL.

The standardization trial was held on February 28th, 1908, beginning at 8·22 A. M. and ending at 12·32 P. M. There were about 325 people on board, comprising Government

representatives, shipyard officials and crew. About 740 tons of coal remained on hand. The vessel carried no other water than reserve feed and was ballasted by handling the coal. The draught and displacement both at beginning and end of the trial was:

	Beginning.	End.
Draught, forward, feet and inches	16-02⅝	15-11¼
aft, feet and inches	17-00⅝	17-00½
mean, feet and inches	16-07⅝	16-06
Displacement, tons	3,720	3,673
Estimated mean draught at middle of five high-speed runs, feet and inches	16-06¾	
Corresponding displacement, tons	3,696	

The weather was fair, with a light mist at the beginning, gentle breezes from the westward, and a smooth sea with a very light swell from the S.E. Seventeen runs were made over the measured mile, alternately north and south. The first three runs were made at about 12 knots, the next three at about 15.5 knots and the next five at full speed, about 25 knots. Following the high-speed runs three runs were made at about 23 knots and three at about 19 knots.

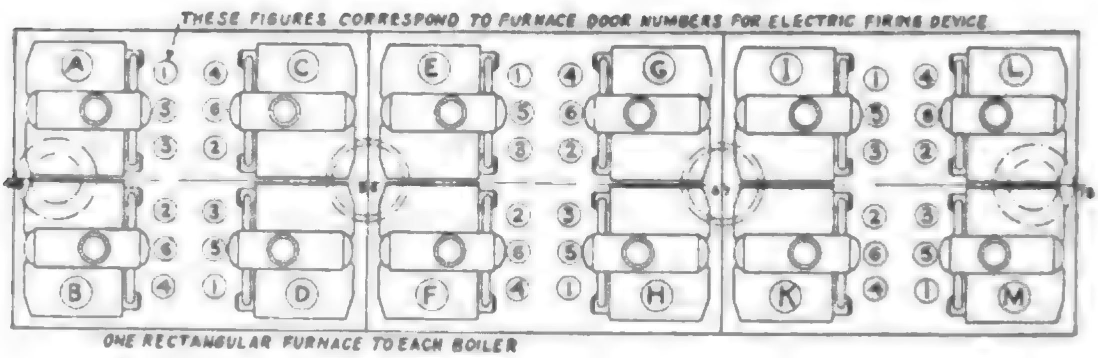
The speed curve was plotted through points determined by taking the mean of the various groups of runs made at each of the five speeds above referred to, and is shown on Fig. 2.

TWENTY-FOUR-HOUR TRIAL AT 12 KNOTS.

At 4.45 P. M. on the same day the *Chester* left the harbor of Rockland for the endurance and coal-consumption trial at 12 knots, the interval between the close of the standardization trial and this time having been utilized for carrying out the anchor test, cleaning the four after boilers, etc. The trial officially began at 5 P. M. The weather was fair and cold, with stiff to fresh breezes from the N.N.W.

On this trial only the after fireroom, boilers I, K, L and M, was used, under natural draft. The following auxiliaries were run: one dynamo, one main feed pump, two main air pumps, two main circulating pumps, two vacuum augmenters, one oil pump, one sanitary pump, steering engine, and

one ash-hoist engine as required. As this run was primarily for the purpose of determining the coal consumption at this speed, coal used was carefully tallied by baskets, though the bunkers were striped, and this latter method relied upon for the exact amount of coal used. The weight of the coal per cubic foot had previously been determined by the Inspector of Machinery, at the works. For this purpose the weight of a bin of coal, containing about 55 cubic feet, was taken. The firing interval on this run was from 1 minute and 30 seconds to 2 minutes, and was based on supplying three shovels, or about 40 pounds, each time. The furnace doors were numbered as shown in the figure. As will be seen, the numbers are so arranged that no two adjacent doors have the same number.



The Corey time-firing device installed displays in succession the numbers 1, 2, 3, 4, 5, 6, at such intervals as desired. It consists of a cylindrical case with a glazed opening near the bottom, back of which there is fixed a fixed white incandescent light. Between the light and the glazed opening there is a revolving aluminum dial, actuated by an electromagnet with stenciled figures from 1 to 6 inclusive. A motor-driven transmitter is located in the forward engine room and so wired to indicators that the numbers will be indicated in all firerooms at the same time. Upon the display of a number the furnace doors bearing that number were opened and the fires therein coaled or raked, the latter being left to the judgment of the fireman. This general practice was followed throughout the succeeding trials.

During this run the eight boilers in No. 1 and No. 2 firerooms were cleaned preparatory to the *full-speed* trial.

All six turbines were in use, steam being admitted to the H.P. cruising turbine. All machinery worked most satisfactorily throughout the entire run. The average revolutions per minute were 249.69, corresponding speed 12.2 knots. The total coal burned was 43.832 tons, 6.68 knots per ton of coal.

Draught and displacement :

	Beginning.	End.
Draught forward, feet and inches	16–05$\frac{7}{8}$	16–02$\frac{5}{8}$
aft, feet and inches	16–11$\frac{5}{8}$	16–09$\frac{7}{8}$
mean, feet and inches	16–08$\frac{3}{4}$	16–06$\frac{1}{4}$
Displacement, tons	3,750	3,671
Estimated mean draught at middle of trial, feet and inches	16–07$\frac{7}{16}$	
Corresponding displacement, tons	3,710	

FOUR-HOUR FULL-POWER TRIAL.

At the conclusion of the last trial, at 5 P. M., February 29, it was necessary to enter port, clean fires and prepare for the *full-speed* trial. The ship proceeded to Portland, Me., and anchored at 5·45 P. M. The four after boilers were cleaned, a load of fresh water taken from a tug boat and the ship ballasted with salt water.

Steam was raised on all twelve boilers.

At 1·30 A. M., on the morning of March 1, the *Chester* left port and at 2·5 A. M. the full-power trial officially began. Bagged coal was used entirely on this run. The four main turbines were used, the cruising turbines running idle in a vacuum. The entire installation worked to perfection. No trouble was experienced with auxiliaries except that the main feed pumps were taxed beyond their capacity and the auxiliary feed pumps had to be used. The auxiliary feed pump in No. 1 fireroom was in use most of the time, that in No. 2 fireroom was run slow a greater part of the time and that in No. 3 fireroom kept in reserve.

The weather was clear and cold with moderate W.N.W.'ly breezes and the sea smooth.

The boilers supplied steam without effort; safety valves were set at about 262 pounds, and steam necessary to main-

tain about 240 pounds at the turbines was kept from beginning to end. The firing interval used was 20 seconds.

The following statement shows the draught and displacement on leaving port and at end of trial:

	Beginning.	End.
Draught, forward, feet and inches	16–04½	15–07⅝
aft, feet and inches	16–10¾	16–09
mean, feet and inches	16–07⅝	16–02 5/16
Displacement, tons	3,731	3,583
Estimated mean draught at middle of run (8 inches by the stern), feet and inches	16–06	
Corresponding displacement, tons	3,673	

TWENTY-FOUR-HOUR TRIAL AT 22.5 KNOTS.

Upon the conclusion of the full-power trial at 6·05 A. M., March 1st, the *Chester* proceeded to Portland, Me., for water and for the purpose of cleaning boilers and otherwise preparing for the *endurance* and *coal-consumption* run at 22.5 knots. Owing to bad weather departure was delayed until 10·14 A. M., March 3d. The draught and displacement on leaving and at end of run was as follows:

	Beginning.	End.
Draught, forward, feet and inches	16–11 15/16	15–09⅝
aft, feet and inches	16–10 9/16	16–08¼
mean, feet and inches	16–11¼	16–02⅞
Displacement, tons	3,835	3,596
Estimated draught at middle of run, feet and inches	16–07¼	
Corresponding displacement, tons	3,716	

The contract contained a penalty clause in connection with this trial, as follows: "If the average speed of 22.5 knots cannot be maintained for the twenty-four hours' endurance and coal-consumption trial, it shall be optional with the Secretary of the Navy to reject her, or to accept her at a reduced price and upon conditions to be agreed upon; provided, that if the coal consumed for all purposes on the twenty-four hours' endurance and coal-consumption trial give an endurance of less than 1.8 knots per ton of coal burned at the speed of 22.5 knots, or less than 1.6 knots per ton of coal burned at a speed of 23.5 knots, or less than a proportionate endurance

per ton of coal burned at other speeds above 22.5 knots, deductions shall be made from the contract price at the rate of $15,000 in each case for every .1 knot of endurance per ton of coal below the endurance required above."

At 10·44 A. M., March 3d, the trial officially began. The weather was overcast and cloudy, with light airs to stiff breezes from N.N.E. to W.N.W., and a smooth sea. The following auxiliaries were in use: Auxiliaries in connection with the operation of the main engines, including two main feed pumps, two dynamos, all hull-ventilating fans, evaporating and distilling plant, flushing pump, forced-draft fans, steering engine, steam heaters, one ice machine at 75 revolutions per minute, and the fresh-water pump as required. All twelve boilers were used under light air pressure. All steam from boilers was admitted to the I.P. cruising turbine; the high-pressure cruising turbine ran idly in a vacuum. Turbines, boilers and auxiliaries, all worked most satisfactorily. Bagged coal entirely was used for the first seven hours. Loose bunker coal used was kept track of as on 12-knot run. The firing interval was one minute.

The trial concluded at 10·44 A. M., March 4th, and was followed by backing, helm, and steering-engine tests. These tests were also held at the conclusion of the *full-speed* trial, but were at this time repeated. With the vessel running at full speed ahead, about 24 knots, the telegraphs were thrown to "full speed astern," and the vessel became dead in the water in 2 minutes and 37 seconds. While running at full speed astern, about 350 revolutions per minute, the telegraphs were thrown to "full speed ahead," and the vessel became dead in the water in about one minute.

With the helm hard over, at full speed ahead, a turning circle, estimated at 700 yards, was completed in 5 minutes and 27 seconds, the initial angle of heel being 30.7 degrees and the permanent angle 1.8 degrees.

While backing full speed the highest steam pressure at astern throttle was 146 pounds, giving about 400 revolutions;

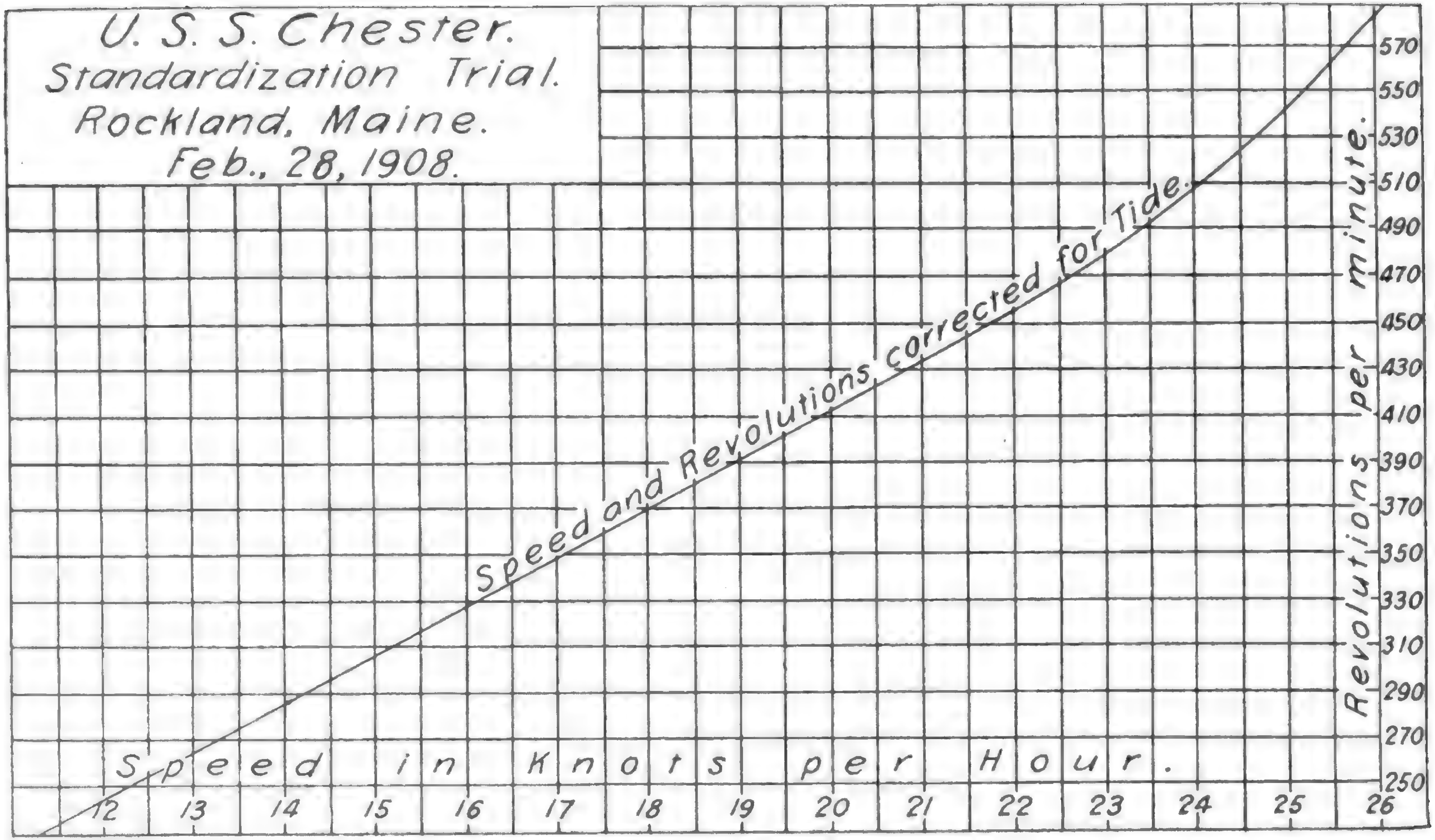
120 pounds gave about 350 revolutions. With the inboard shafts backing at 400 revolutions the outboard shafts ran idle at nearly 200, and with the inboard shafts backing at 350 the outboard ran idle at about 150.

The average revolutions per minute were 473.343, corresponding speed 22.782 knots. The total coal burned was 193.54 tons, 2.82 knots per ton of coal.

STANDARDIZATION TRIAL DATA.

No. and direction of run.	Interval between middle of runs.			Average of elapsed times observed.		Mean revolutions per min.	Speed in knots.
		Min.	*Sec.*	*Min.*	*Sec.*		
1 N.		...	...	5	18.75	251.88	11.2941
2 S.		17	06.3	4	33.35	242.88	13.1700
3 N.		20	02.5	5	18.45	251.07	11.3048
4 S.	about	19	...	3	38.85	317.04	16.4496
5 N.		16	20.1	4	08.90	319.97	14.4637
6 S.		15	51.5	3	33.90	319.65	16.8303
7 N.	about	13	...	2	30.95	545.06	23.8492
8 S.		12	05.7	2	17.75	542.43	26.1347
9 N.		12	11.1	2	29.65	546.69	24.0558
10 S.		12	46.8	2	17.30	545.83	26.2203
11 N.		13	21.7	2	30.50	545.87	23.9206
12 S.	about	17	...	2	28.00	482.68	24.3240
13 N.		15	18.4	2	42.80	486.51	22.1133
14 S.		14	54.5	2	27.70	484.31	24.3734
15 N.		...	...	3	16.05	402.31	18.3627
16 S.		17	04.7	2	35.55	400.24	20.5304
17 N.		16	34.9	3	15.10	400.75	18.4519

The vessel proceeded to Portland, Me., where the Board of Inspection and Survey disembarked, after which she returned to the works of the builders, Bath, Me. The usual custom was observed of painting on the smoke stacks the speed made at full power, and lashing brooms at the masthead and yard-arms. The greater part of the Bath population met the vessel at the dock and a salute was rendered by them of 26 guns, one for each knot made, with a historic cannon belonging to the city.



U. S. S. Chester.
Standardization Trial.
Rockland, Maine.
Feb., 28, 1908.
Speed and Revolutions corrected for Tide.
Revolutions per minute.
570
550
530
510
490
470
450
430
410
390
370
350
330
310
290
270
250
Speed in Knots per Hour.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

Plate II.

GENERAL REMARKS ON THE MACHINERY INSTALLATION AND ON ITS MANAGEMENT AND OPERATION DURING THE TRIALS.

The management of the trial program and of the individual trials reflected great credit upon the builders. The efficient management of the vessel and machinery during the standardization trial is evident by a reference to the table giving the elapsed times between the middle of runs. A full share of credit should be given the boilers as exhibited by the ease in maintaining steam throughout the trials and by the ease with which the vessel was brought up to her first full-speed run (No. 7 standardization run), of 25 knots, following a run at 15.5 knots (No. 6). As noted in the table the interval between the middle of these runs was 13 minutes, of which several were spent in finishing No. 6 run and several included in No. 7 run. The interval in which increased steam was raised was, therefore, about six minutes. Attention is invited to the moderate air pressures carried, as shown on data tables. A high-grade fireroom force was employed, which could have been improved on little. No attempt was made at reducing the complement by reason of the vessel being turbine driven. The engineer complement was made up as follows: 1 chief engineer, 21 engineers, 18 oilers, 6 blower oilers, 6 machinists, 6 messengers, 4 pump men, 3 evaporator men, 2 boiler-makers, 1 steam-heat man, 1 clerk, 9 water tenders, 49 firemen, 28 coal passers and 12 boiler cleaners, arranged in three watches.

Vibration of turbines and hull were practically *nil* at all speeds, a slight tremor only being noticed in the after cabin at top speed, a propeller influence. Both the bow wave and stern wake were remarkably small. The only opportunity for observing the vessel's stability in a sea way was between Bath and Charlestown, when fairly rough weather was encountered. At this time the period of a double roll was thirteen seconds. The machinery weights were slightly under the limit of 798 tons, whereas the horsepower developed was

much greater than the designed 16,000. The machinery compartments were never uncomfortably warm, though it must be remembered that the weather was cold and the ventilation especially efficient. The oil service worked most satisfactorily and bearing temperatures were in no case excessive. The coal used on the trial was Pocahontas, and samples of the lots used on the various trials were tested with the following results:

Selected Pocahontas coal.	4-hour test.	24 hours at 12 knots.	24 hours at 22.5 knots.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	1.18	1.18	1.16
Volatile matter	19.50	20.14	20.21
Fixed carbon	75.78	75.54	76.03
Ash	3.54	3.14	2.60
Total	100.00	100.00	100.00
Sulphur	0.61	0.60	0.61
Heat value in B.T.U.	14,740	14,830	14,896

Arrangements were made by the contractors for obtaining water-consumption data by a system of measuring the feed-pump volumes, but as the data obtained was not considered reliable it is omitted from these papers.

POST-TRIAL EXAMINATION OF BOILERS AND MACHINERY.

Instructions were given the builders by the Trial Board upon the conclusion of the trials to have the boilers opened for complete inspection, all turbine covers lifted, and other features of the installation prepared for post-trial examination in accordance with current practice. A report was made by the builders on the 7th of March that they would be ready on the 9th instant. The Trial Board arrived at Bath on that date. The examination showed the boilers to be in fine condition, a small amount of brickwork having been re-made, and the turbines and auxiliaries in excellent shape. Indications of blades having rubbed (in spots) were noticed in the

four main turbines, but this was not sufficient to warrant anxiety or to necessitate other than slight reduction in tip clearances here and there. The journal-bearing bridge-gauge clearances taken after trial were:

BRIDGE-GAUGE MEASUREMENTS ON JOURNAL BEARINGS.

H.P. C., forward bearing	.018
after bearing	.027
I.P. C., forward bearing	.032
after bearing	.012
Starboard H.P., forward bearing	.038
after bearing	.010
Starboard L.P., forward bearing	.022
after bearing	.021
Port H.P., forward bearing	.023
after bearing	.008
Port L.P., forward bearing	.019
after bearing	.002

Following the trials and this examination, work in connection with the final completion of the vessel for delivery to the Government was begun. This consisted principally in laying linoleum, cleaning, painting, lagging, etc., and making good what few minor defects were noted, such as leaky valves, joints, etc. Journal bridge-gauge clearances were taken, other such data collected, and stores assembled. The vessel was finished on April 23, 1908, and, ten days before the expiration of the contract time, on April 24th, she was taken to the Navy Yard, Portsmouth, N. H., and there delivered to Rear Admiral Bicknell, U. S. N., the Commandant of the yard.

The vessel was secured at the dock at noon, and at 2 P. M. the Board of Inspection inspected the vessel, finishing at 3.45 P. M. Promptly upon the conclusion of the inspection the ship was taken over and the engineer department relieved by a tentative organization. The ship was placed in commission at 10 A. M. April 25th.

DESCRIPTION OF PROPELLING MACHINERY.

The propelling turbines are in general as set forth at the beginning of the article, six in number, an H.P. cruising, I.P. cruising, two main high pressure and two low pressure, with reversing turbines incorporated into the exhaust ends of each of the latter. The reversing turbines revolve idly in the exhaust casing of the L.P. turbine when the engines are running ahead. Arrangement has been referred to in Figure No. 1. As shown therein, they are located in two compartments separated by an athwartship, watertight bulkhead. The inboard shafts turn outboard and the outboard shafts turn inboard.

The turbine cylinders are parted horizontally in the plane of the shaft, and the two halves strongly bolted together. The lower half is cast with extensions forward and aft, box shaped, for retaining the journal and thrust bearings. The cylinders are supported by feet, certain of which are securely bolted to the foundations and others have slotted holes for expansion. The feet are at a point directly under the journal bearings. The cylinders contain supports for the spindle and thrust-bearing brasses with oil pockets, also the lower halves of spindle glands, and have pockets under these glands for steam leak-offs. They have internal facings at their ahead steam ends for bolting on the dummies. Cylinder blading is calked into grooves on the inside of the cylinder castings, these portions of the cylinders having been accurately bored and finished in a horizontal position. Hydrostatic tests were first applied to the cylinders, and subsequently a "baking" under moderate steam pressure for 48 hours to relieve internal stresses in the castings. The following table shows arrangement and dimensions of blading.

The rotors were statically balanced on two truly-leveled rails and the balance adjusted by removing metal, as necessary, from "chipping strips" left on the arms of the rotors for the purpose. The dynamic balancing was done by revolving the rotors under steam. At the same time dummy ring faces were worn down, and bearings adjusted.

Stages.	Expansions.	Rows.	Heights, Inches.	Pitch, Inches	Clearances, Inches.
			H.P. Cruising.		
1st	1st	12	$\frac{3}{8}$	$\frac{7}{8}$	.03
2d	2d	12	$\frac{1}{2}$	$\frac{7}{8}$	.035
3d	3d	12	$\frac{5}{8}$	1	.04
			I.P. Cruising.		
1st	1st	15	$1\frac{1}{8}$	$1\frac{1}{4}$	.04
2d	2d	15	$1\frac{7}{16}$	$1\frac{1}{4}$	.04
3d	3d	15	$1\frac{5}{8}$	$1\frac{5}{16}$	.045
			Main High Pressure.		
1st	1st	12	$\frac{7}{8}$	$1\frac{1}{4}$	.03
2d	2d	12	$1\frac{1}{4}$	$1\frac{1}{4}$	.035
3d	3d	12	$1\frac{3}{4}$	$1\frac{5}{16}$	.04
4th	4th	12	$2\frac{1}{2}$	$1\frac{3}{8}$	.045
5th	5th	12	$3\frac{1}{4}$	$1\frac{7}{16}$	.05
6th	6th	10	5	$1\frac{13}{16}$	.05
			Main Low Pressure.		
1st	1st	5	$2\frac{1}{4}$	$1\frac{5}{16}$	.055
2d	2d	5	$3\frac{1}{4}$	$1\frac{3}{8}$	.06
3d	3d	4	5	$1\frac{13}{16}$	.07
4th	4th	3	7	$1\frac{3}{4}$	.08
4th	5th	3	7	$1\frac{13}{16}$	.08
4th	6th	4	7	$2\frac{1}{16}$	.08
4th	7th	4	7	$2\frac{5}{32}$	.08
			Astern Turbines.		
1st	1st	6	$\frac{1}{2}$	$1\frac{1}{4}$	.045
2d	2d	6	1	$1\frac{3}{8}$	.05
3d	3d	6	2	$1\frac{3}{8}$	.06
3d	4th	6	2	$1\frac{1}{2}$	.06
3d	5th	6	2	$1\frac{1}{2}$	.06

The blades were installed in accordance with the Parsons system. They were cut to length, saw-cuts made where required for binding, calking grooves stamped into the base of the blades, all done by the same machine, and the blades then calked into place. Calking strips having curves corresponding to the blades were cut to length and placed alternately at the base of each blade. The blades and calking strips were

alternately tightened into the groove by means of a calking tool, after which the binding wire was inserted and the lacing put on around binding wire and blades with silver solder. Blades were turned up in the vertical line before the insertion of the binding wire, and were finally filed up to remove burrs.

The blades are of a composition consisting of 72 per cent. copper and 28 per cent. zinc, the calking strips $63\frac{1}{2}$ per cent. copper and $36\frac{1}{2}$ per cent. zinc, the binding strip 72 per cent. copper and 28 per cent. zinc, and the lacing wire pure copper. Blades having binding strips are soldered to the latter with a silver solder. Steam supply and exhaust piping is as shown on Fig. 1. In the exhaust pipe from H.P. cruising turbine to I.P. cruising turbine, and in the two exhaust pipes from the I.P. cruising to the main H.P. turbines, spring-loaded, self-closing valves are installed to isolate the cruising turbines while running at higher rates of speed and while maneuvering. A $3\frac{1}{2}$-inch spring-relief valve for the H.P. cruising turbine is installed in its exhaust pipe, set at 125 pounds, and one for the I.P. cruising turbine is installed on after end of its upper casing, set at 160 pounds. A governor, arranged to pull out a pawl and close a butterfly valve in the main steam pipe, is fitted on each shaft, the object being merely to shut down automatically in the event of accident. An unusual feature in piping is the low-pressure exhaust pipe, which is an elbow pipe rectangular in cross section, 3 feet 9 inches by 4 feet 6 inches and of $\frac{3}{8}$-inch steel plate. The dummies in the steam ends of turbines for preventing steam from leaking from steam belts direct to the inside of drums consist of a series of rectangular grooves in the spindle wheels against the side of each of which a brass strip lies closely without touching. These brass strips are calked into an annular iron casting made in halves and bolted to the inside of the cylinder. A micrometer for measuring the opening of dummies between brass strips and running steel faces is fitted on each cylinder. Steam glands are fitted around turbine spindles at cylinder ends, packed with labyrinth stuffing boxes. These glands are to obviate, in the case of high-pres-

sure turbines, the leakage of steam from the casings, and in the case of the low-pressure turbines, the leakage of air from the atmosphere into the casing and thence to the condenser. There are rows of brass strips let into the shaft and the cast-iron gland sleeve, with thin edges just clearing the opposite member. Snap rings of composition H are fitted at the outer end of each gland box, and just inside of these rings connection is made with an equalizer pipe joining all similar pockets, and a valve is provided from auxiliary exhaust line for maintaining the pressure in this pipe. Strainers of the basket type in accordance with current turbine practice, made with bodies and covers of composition G, and with strainer baskets of sheet brass, are installed, one in the live-steam supply to each turbine and one in the auxiliary exhaust connection to the second expansion of the main H.P. turbines and L.P. turbines. A system of guide rods is installed for lifting turbine casings, one on each of the four corners, placed vertically and graduated in inches, to permit of the even lifting of the covers. Special portable guides are supplied for guiding the spindles when lifting them, to prevent the stripping of blades. Turning gear is fitted at the after end of each turbine for turning it by hand. It consists of a wormwheel on the shaft, meshing with a worm operated by a ratchet wrench. Suitable lifting gear is provided for lifting casings, spindles, etc., consisting of overhead trolleys on frames, with chain falls and slings. Turbine cylinder data follows:

Cylinder.	Diam. of rotor drum, inches.	Length of rotor drum, inches.	Diameter of cylinder for each stage.						
			1st inches.	2d inches.	3d inches.	4th inches.	5th inches.	6th inches.	7th ins.
H.P. cruising	60	36	$60\frac{5}{8}$	61	$61\frac{1}{4}$	...	...	...	...
I.P. cruising	49	60.5	$51\frac{1}{4}$	$51\frac{7}{8}$	52.5	...	...	...	...
Main H.P. port	42	103.5	$43\frac{3}{4}$	44.5	45.5	47	49	52	...
starboard.	42	103.5	$43\frac{3}{4}$	44.5	45.5	47	49	52	...
L.P. port	65	$53\frac{5}{8}$	70	72	75	79	79	79	79
starboard.	65	$53\frac{5}{8}$	70	72	75	79	79	79	79
Astern, port	50	43	51	52	54	54	54	...	...
starboard	50	43	51	52	54	54	54	...	...

SHAFTING AND SHAFT BEARINGS.

The shafting is of Class "A" forgings and is solid. The thrust shaft is on spindle ends. The stern-tube shaft and propeller shaft is in one piece, inboard sections 48 feet 3 inches long and outboard lengths 46 feet 9 11/16 inches long, in both cases 8½ inches diameter. The line shafting is 8 inches in diameter. There are two shaft bearings to each turbine—twelve in all—those for the cruising turbines being 10 inches long and those for the main turbines 15 inches. The bearing shells, of brass, are semi-circular and are lined with white metal. Broad strips of the bearing shell are exposed slightly below the line of the white metal to catch the spindle in case the white metal gives out. The bottom half can be rolled out without lifting the spindle, the top half will lift off. These bearings are lubricated by oil supplied under pressure. There are six thrust-shaft bearings, those for the cruising turbines having eight collars and rings, those for main turbines fifteen collars and rings. These bearings are so constructed that the longitudinal position of the shaft and the dummy clearance can be readily adjusted. The thrust bearings are in two halves. The steam balance is so arranged as to be practically equal to the thrust of the propeller at all speeds. The thrusts are lubricated by oil under pressure. Oil supplied to thrust bearings and journal bearings is collected in a chamber in the box ends of lower cylinder castings, and drains by gravity into a return pipe. There are fifteen line-shaft bearings each 12 inches long, lined with white metal, and with ends provided with oil baffles; provision is made for their lubrication by oil under pressure. Water service to a jacket around oil chambers is provided only in case of line-shaft bearings, the water-service pipe discharges into stern-tube stuffing box and has a branch pipe for draining the latter. Water service by hose can be provided in emergency. Stern-tube bearings for each shaft consist of a bearing in each end of the tube in each case. They are each 51⅜ inches in length. Each shaft also has one strut bearing, 51⅜ inches in length, and fair-water sleeves are fitted on the forward side of the strut at one end,

and on the after side of the stern tube at the other. There are sixteen bulkhead stuffing boxes where shafts pass through watertight bulkheads.

An expansion coupling is fitted between each L.P. turbine and the cruising turbine on same shafting. The forward end of each L.P. turbine shaft is built with 12 teeth which engage with a slotted collar bolted to the flange coupling on after end of cruising-turbine shafting. This permits of disconnecting cruising turbines, as well as of expansion. As but slight increase efficiency is gained by disconnecting, this is not done as a rule, the cruising turbines being run idle in a vacuum when not in use.

PROPELLERS.

There are four solid, true-screw, manganese-bronze propellers, each having three blades; diameter, 6 feet; pitch, 6 feet; area, projected, 17.02 square feet; helicoidal, 19 square feet; disk area, 28.27 square feet; immersion of upper tip of blade, 69½ inches, inboard, 57½ inches, outboard. The driving surfaces of all propeller blades were made a true surface by machining. The wing propellers are ahead of the inner propellers, and the former turn inboard and the latter outboard, though it was originally intended that all four turn outward.

MAIN CONDENSERS.

There are two main condensers, one in each engine room, located inboard and abreast of each L.P. turbine. They are horizontal and cylindrical, of the surface-condensing type. The shells are made of Class "B" boiler plate, water chests of composition, tubes of composition and tube sheets and supporting plates of "rolled naval bronze." The forward water chest, being the one for the entrance and exit of circulating water, has a division plate with a 7-inch by-pass valve on outside of chest. Each water chest has eight 10-inch manholes fitted with composition covers, inside of which are placed zinc plates. The following is the data for each :

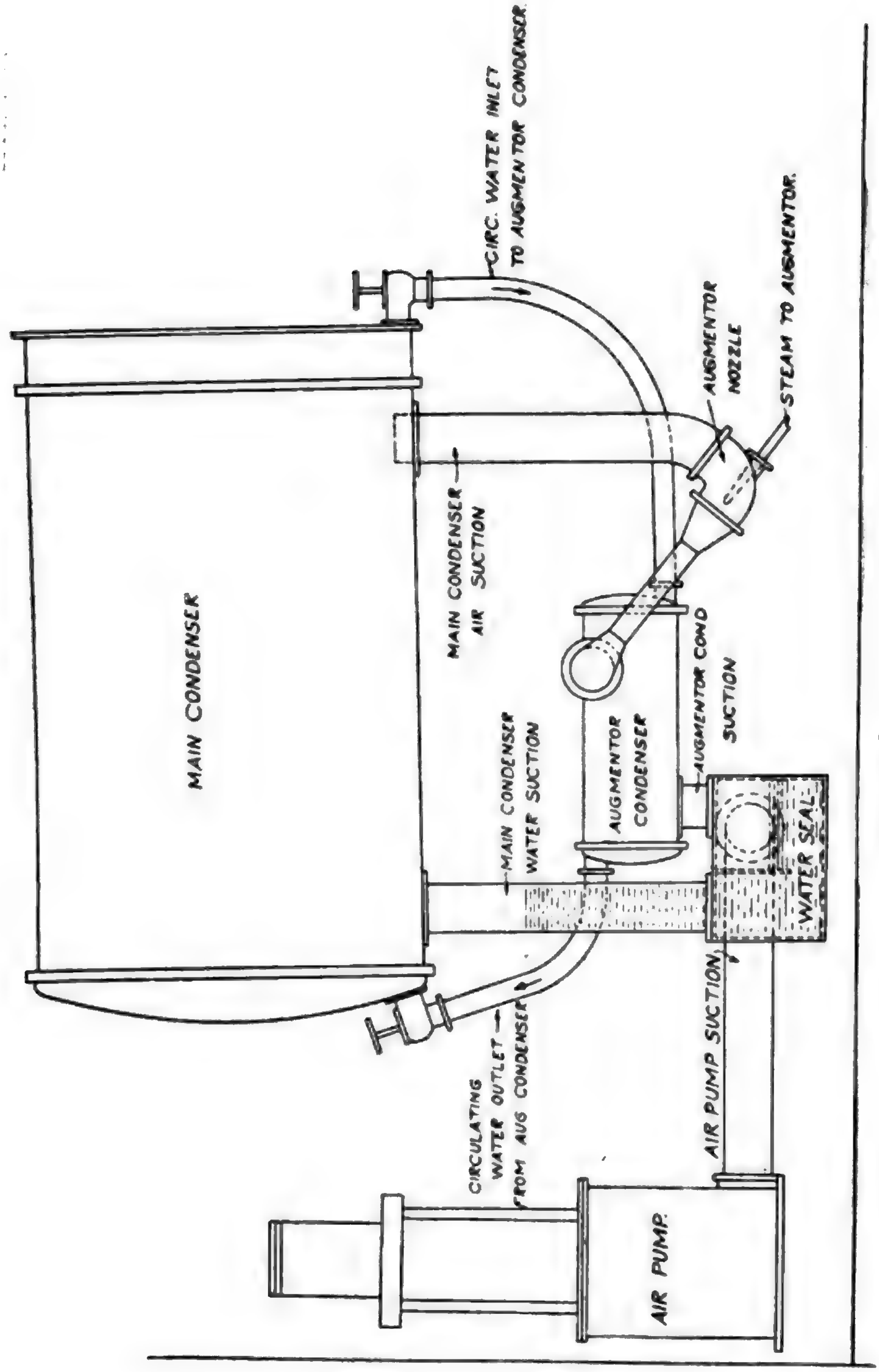

MAIN CONDENSER
CIRC. WATER INLET TO AUGMENTOR CONDENSER
AUGMENTOR NOZZLE
STEAM TO AUGMENTOR
MAIN CONDENSER AIR SUCTION
AUGMENTOR COND SUCTION
AUGMENTOR CONDENSER
MAIN CONDENSER WATER SUCTION
WATER SEAL
AIR PUMP SUCTION
CIRCULATING WATER OUTLET FROM AUG CONDENSER
AIR PUMP

FIGURE 3

Cooling or heating surface, square feet	8,999
Number of tubes	5,630
Thickness of tubes B.W.G.	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	10–0$\frac{1}{4}$

AUGMENTER CONDENSER.

An arrangement called a "vacuum augmenter," devised by the Parsons Turbine Company, is installed for the purpose of increasing the vacuum above that obtained by the air pump.

The augmenter consists of a steam syphon drawing air from the condenser and discharging it to the air-pump suction at a pressure from 1 to 1$\frac{3}{10}$ inches of mercury higher than the condenser pressure. The discharge from the syphon passes through a small condenser in order to condense the steam of the syphon jet. The air pump also has a direct water suction from the condenser through a pipe having a water seal and holding a head of water equal to the difference in pressure produced by the augmenter jet. The augmenter was in use at all times during the trials and produced an increase in vacuum of from 1 to 1$\frac{1}{4}$ inches.

AUXILIARY CONDENSER AND DYNAMO CONDENSER.

There is one auxiliary condenser located on the port side of the forward engine room. It is horizontal, cylindrical, and of the surface-condensing type, connected, through the auxiliary exhaust pipe, to all auxiliary machinery. It is only for use in port. Its dimensions are as follows:

Cooling or heating surface, square feet	601
Number of tubes	630
Thickness of tubes B.W.G.	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	6–0$\frac{9}{16}$

A similar condenser is located in the dynamo room for the exclusive use of the dynamo engine. Its dimensions follow:

Cooling or heating surface, square feet	202
Number of tubes	212
Thickness of tubes B.W.G	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	$6-\frac{9}{16}$

FEED HEATERS.

A vertical, dead-end, cylindrical feed-water heater is located at the forward end of each engine room on the discharge side of the main feed pumps. The heating agency is steam from the auxiliary exhaust line, which enters the shell at the top, circulates around the tubes over a system of baffles, and drains at the bottom through a trap to the condenser. An air coil is fitted in the lower water chest, with one end extending into the heater to a point where air forms between the water and the steam. This coil leads direct to the condenser. A drain at the bottom of the heater conducts the condensed water to a trap, thence to the condenser. The feed water passes through the tubes. The tubes contain twisted brass strips held in place by a perforated plate over the tube sheet to retard its flow and insure efficient heating. The dimensions of the heater are as follows:

Heating surface, square feet	601
Number of tubes	630
Thickness of tubes B.W.G	16
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	$6-1\frac{5}{8}$

FEED AND FILTER TANKS.

There are located in the after part of each engine room combined feed and filter tanks, each of about 1,500 gallons capacity. A partition divides each tank into two parts, one part being for the filter and the other for feed tank proper. The capacity of the former is about 300 gallons and of the latter about 1,200 gallons. The filter has an inner bottom of bolted perforated plates, and is divided by a series of vertical partitions. The partition plates are in pairs, one secured to the top and the other to the bottom of the filter; the passage

of water from one chamber to the next being under the hanging partition plate, up between the two and over the top of the standing partition. The entering water flows into the first chamber over the top of a plate and leaves the last chamber in like manner, these plates forming, with the sides of the tank, entrance and exit chambers, insuring that the filter chambers are always filled and the filtering material submerged.

STEERING GEAR.

The vessel is fitted with a Hyde Windlass Company's steam-steering engine, the operating valve of which is controlled by a telemotor located in the pilot house. This telemotor is connected up with a line of piping to another telemotor located on the steering engine in the steering-engine compartment aft, from which this controls the operating valve. The operating valve of the engine also closes automatically when the rudder has moved to a position corresponding with the number of turns given the steering wheel. The power is transmitted to the rudder head by the customary right and left-handed screw shaft. The vessel can be steered by steam as follows, viz: (a) the bridge; (b) the pilot house; (c) the steam-steering engine itself; and (d) by hand from the steering-engine room.

Also a direct hand steering is provided for an emergency by an arrangement of relieving tackles, direct-connected to the crosshead on rudder head. The power is transmitted to the rudder head by having a tackle passed around a drum, the drum being connected by a spur-wheel, gear and pinion through a worm and wheel to the hand-steering wheels. A clutch is provided on the worm shaft for disconnecting the emergency gear from the hand-steering wheels. There is fitted over the screw shaft a positive helm-angle indicator, and before connecting up for steering from any given position this indicator and all other indicators should be in the central position, or in same relative position to each other. There is further fitted a friction brake on the rudder head

operated by a hand wheel just forward of bulkhead No. 131, which brake is of sufficient power to lock or hold the rudder while shifting steering positions or making repairs. On the forward bulkhead in the steering-gear room is an oil tank for oiling the gear, which should never be allowed to become empty. From it pipes are led to the bearings and crosshead. Except when in actual use cocks in the piping should be kept closed. The hand-steering wheels are always disconnected when steering by steam.

DATA.

Number of cylinders in engine	2
Diameter of cylinders in engine, inches	12
Stroke, inches	10
Steam working pressure, pounds	150
Total area of rudder, square feet	195
Area of balanced portion, square feet	33
Radius of crosshead, inches	28
Angle of rudder between steering-engine stops from hard-a-starboard to hard-a-port, degrees	70
Angle between stops on stern post, degrees	76
Diameter of turning circle with rudder hard over, yards	about 500

ANCHOR WINDLASS.

The windlass is of the worm-gear type, with vertical wildcat shaft and gypsy heads, built by the Hyde Windlass Company. The engine is an inverted, vertical, compound engine, with H.P.-cylinder diameter 10 inches, L.P. cylinder 12 inches, and a stroke of 10 inches.

EVAPORATING AND DISTILLING PLANT.

This plant is made up of four evaporators and four distillers, the former being located in an evaporator room over forward end of forward engine room. The evaporators have a combined capacity of 16,000 gallons of water per day and the distillers a combined capacity of 16,000 gallons of potable water per day. The distillers are located in a trunk leading up from the evaporator room. The evaporators are of the

usual navy type, built by the Bath Iron Works, and each has 223.7 square feet of tube-heating surface; the tubes are 2 inches outside diameter No. 12 B.W.G. and number 84 for each evaporator. The distillers have 80.5 square feet of cooling surface each, tubes are $\frac{5}{8}$-inch outside diameter, No. 16 B.W.G., and straight; number for each distiller, 127. The steel flanges on the shell of the distillers are made in the form of a diaphragm to take up the shell expansion, obviating the necessity for a stuffing box.

REFRIGERATING PLANT.

The refrigerating plant is located on the orlop deck slightly forward of the machinery space. Two vertical, one-ton, Allen dense-air ice machines are installed, one on either side of the compartment, with connections to cold-storage rooms, scuttle butt and ice-making box. The refrigerator is made up of an officers' cold-storage room to starboard and a crew's cold-storage room to port, with an entry between, the latter opening into the ice-machine room, and inside to both of the storage compartments. A manifold regulates the combinations in which the different circuits may be run.

HEATING PLANT.

Radiators are installed in the various parts of the ship for steam heat. The system is divided into eight circuits, in two groups. The forward group comprises the heaters for the chart house and emergency cabin, general pantry and sick bay, crew's quarters, galley and bath heaters. A valve system for regulating the latter is located in the forward uptake, port side. The after group comprises the heaters for the pantries and bath heaters aft, captain's quarters, wardroom officers' quarters, warrant officers' quarters and steering-engine room. The valves for regulating the after group are located over the feed tank in the after engine room. Provision is made for heating water in all lavatories and bath rooms with steam.

ASH HOISTS.

One ventilator in each boiler compartment is fitted for the necessary gear for hoisting ashes to the main deck. One ash-hoist engine of Hyde Windlass Company type is fitted in each case, and is of sufficient power to hoist 300 pounds from the fireroom floor to the upper deck in 5 seconds under steam at 150 pounds pressure. Each engine has two cylinders with cranks at right angles with follow-up gear. Data as follows: 4½-inch stroke, 4½-inch cylinder diameter.

There is also installed in each fireroom on the port side outboard an ash ejector of the See type. These ejectors are connected to the fire and bilge pumps, and discharge five feet above the water line. The hoppers are proportioned to discharge at least 4 cubic feet of ashes per minute.

FORCED-DRAFT BLOWER SYSTEM.

The closed-fireroom system is fitted, two 5×5 double upright blower engines of B. I. W. design being installed for each boiler compartment, making a total of six. They are located near the center line of the ship over their respective compartments on the orlop deck. Their dimensions are as follows: Diameter of steam cylinder, 5 inches; diameter of piston rod, 1⅛ inches; stroke, 5 inches. The blowers are arranged in pairs, with a connecting shaft between the two fans, so that both fans run at the same speed and, in case of accident to one engine, both fans may be run with the remaining engine. The fans are 84 inches in diameter, with nine vanes, and discharge from the periphery ends of vanes.

LUBRICATION.

The lubrication of all main-journal bearings, thrust bearings and line-shaft bearings is by oil supplied under about 10 pounds pressure by steam-driven oil pumps. The oil passes through a cooler on its way to the bearings. Tanks of 150 gallons capacity are located in the lower parts of engine rooms, one in each, from which the oil pumps draw. These

tanks take the return of the oil from all bearings supplied with forced lubrication, by gravity. The discharge of the oil from turbine bearings is through glasses so that the flow can be observed, and thermometers are fitted to these discharges. The oil pipes are all of copper and have no valves fitted either to or from the bearings. Two pumps, Blake, vertical, simplex-piston type, $10 \times 9 \times 12$, are supplied, one in each engine room. Either or both may be used. An oil cooler of the surface-condenser type, with oil passing through the tubes and the water around them, is provided in each engine room. The oil passes four times the length of the cooler by means of bridges in the oil heads. The circulating water is taken from either the engine-room fire and bilge pumps or main circulating pumps, and discharges through outboard delivery pipes. Additional oil may be supplied to the forced-lubrication system by an overhead gravitation system from the tanks containing reserve oil. The outlets for oil in the casings are at a high level, so that there is always in the casing wells a large gathering of oil which is at about the same temperature as the shaft.

MAIN AIR PUMPS.

Two independent Blake, vertical, twin-beam air pumps, $14 \times 35 \times 21$, are installed, one for each engine room. The suction openings are 12 inches in diameter and the discharge 11 inches. The air-pump suctions take from the lower end of the vacuum-augmenter condensers and water seals (see vacuum-augmenter condenser and Fig. 3).

MAIN CIRCULATING PUMPS.

For each main condenser there is one main circulating pump, centrifugal, with vertical compound engine of B .I. W. design, steam cylinders, 10 inches and 16 inches in diameter; stroke, 10 inches; 42-inch diameter runner. Each pump is of sufficient power to discharge 11,000 gallons of water per minute at about 360 revolutions. Each pump is fitted with pipes and valves to draw from the sea and the main drain and

to deliver into the condenser or overboard through valves in the condenser water chest. Circulating water for oil coolers may be supplied from these pumps.

AUXILIARY AIR AND CIRCULATING PUMP.

For the auxiliary condenser there is installed one simplex, horizontal, combined air and circulating pump of Blake type, $6 \times 10 \times 10 \times 12$. This pump has suction pipes from the auxiliary condenser and the sea, and discharge pipes to main feed tanks and to auxiliary condenser. Curves of indicated horsepower are shown in Figure 7.

AUXILIARY AIR AND CIRCULATING PUMP (DYNAMO ROOM).

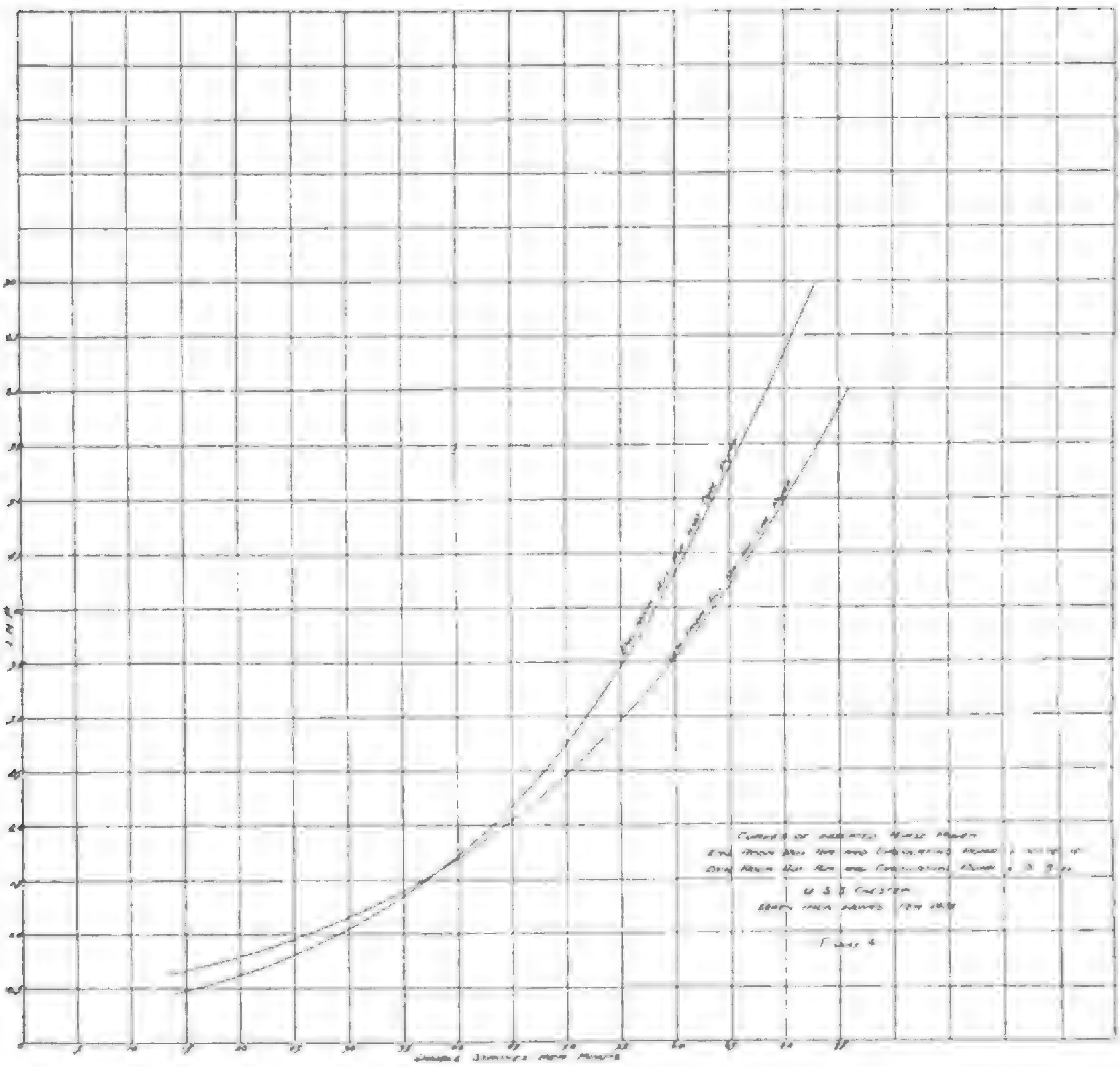
This pump is for serving the dynamo auxiliary condenser, and is a simplex, horizontal, combined air and circulating pump, $6 \times 8 \times 8 \times 12$, of Blake type. Its connections are similar to those for the other auxiliary air and circulating pump. Curves of indicated horsepower are shown in Figure 4.

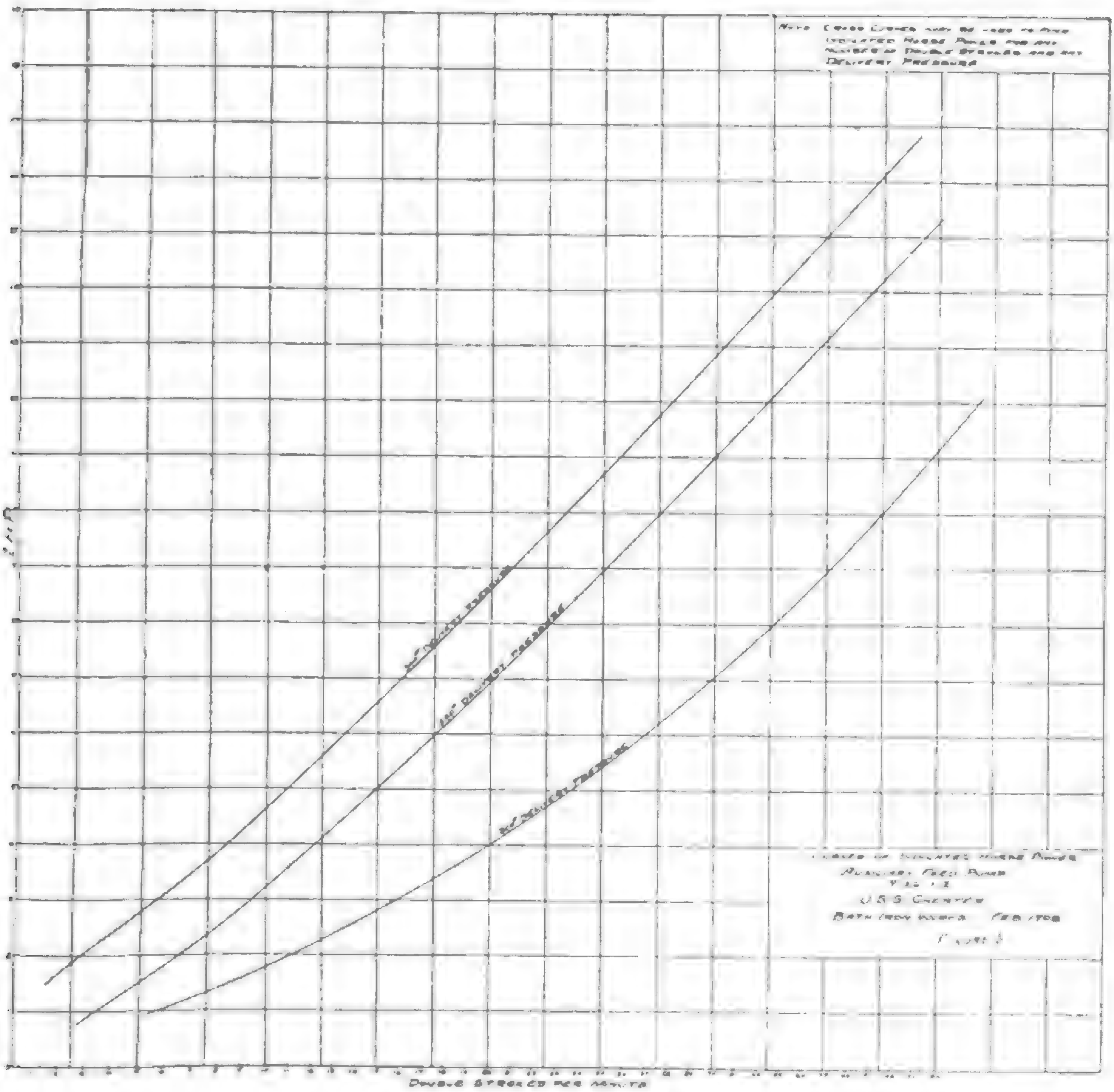
MAIN FEED PUMPS.

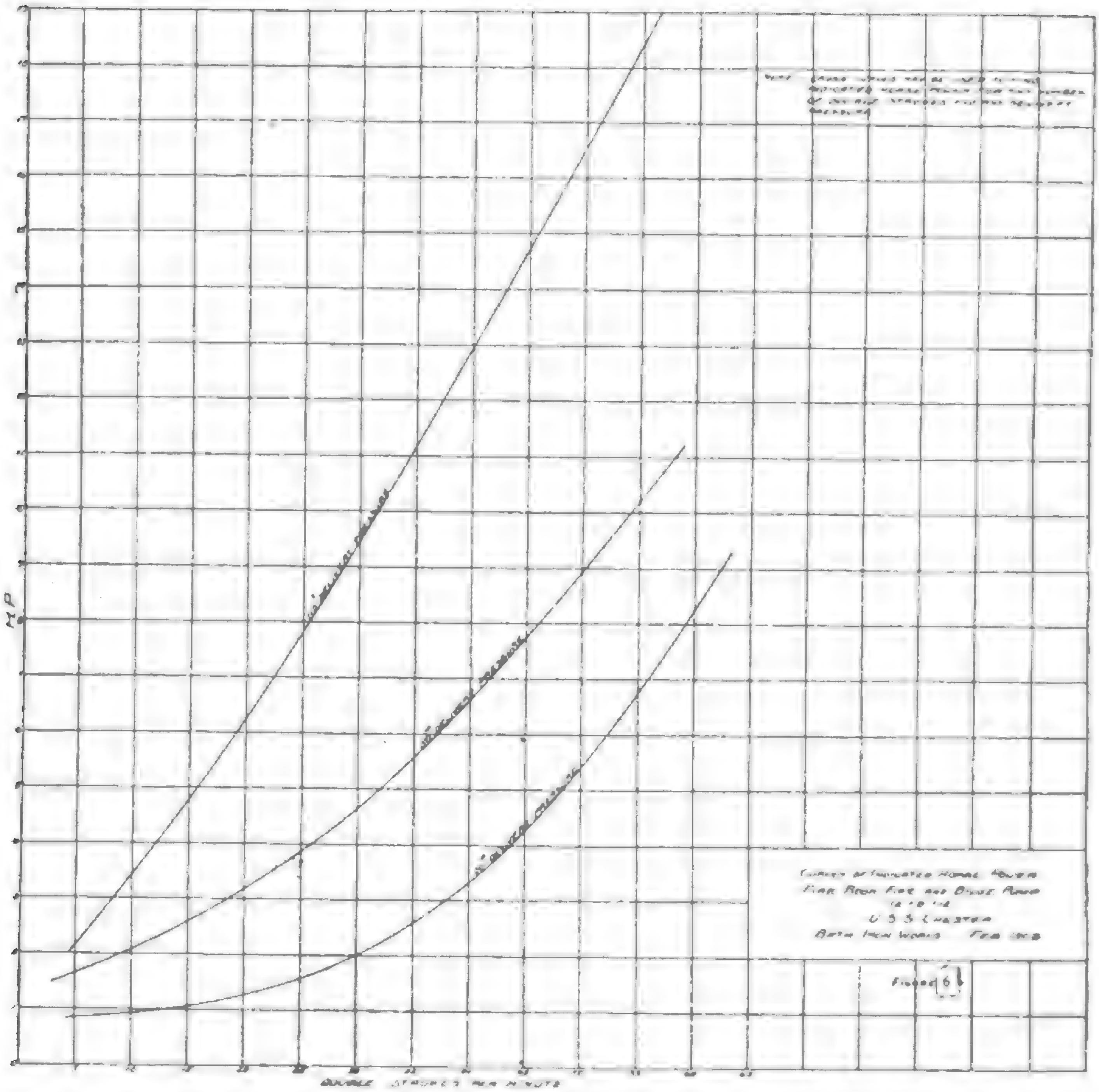
There are two Blake, vertical, simplex, piston, feed pumps, $15 \times 10 \times 15$, one in each engine room. They take their suction from feed-tank connecting pipes or channel ways and discharge through grease extractors into the main feed discharge, directly or through the feed-water heaters.

AUXILIARY FEED PUMPS.

Three Blake vertical, simplex, piston, feed pumps, $9 \times 6 \times 12$, are installed for auxiliary feed purposes, one in each fireroom. These pumps have suction pipes from boiler bottom blows in same compartment, main feed tanks and feed suction pipe. They discharge as auxiliary feed and overboard in same compartment, and to main feed tanks and to fire extinguishers. Curves of indicated horsepower are shown in Figure 5.



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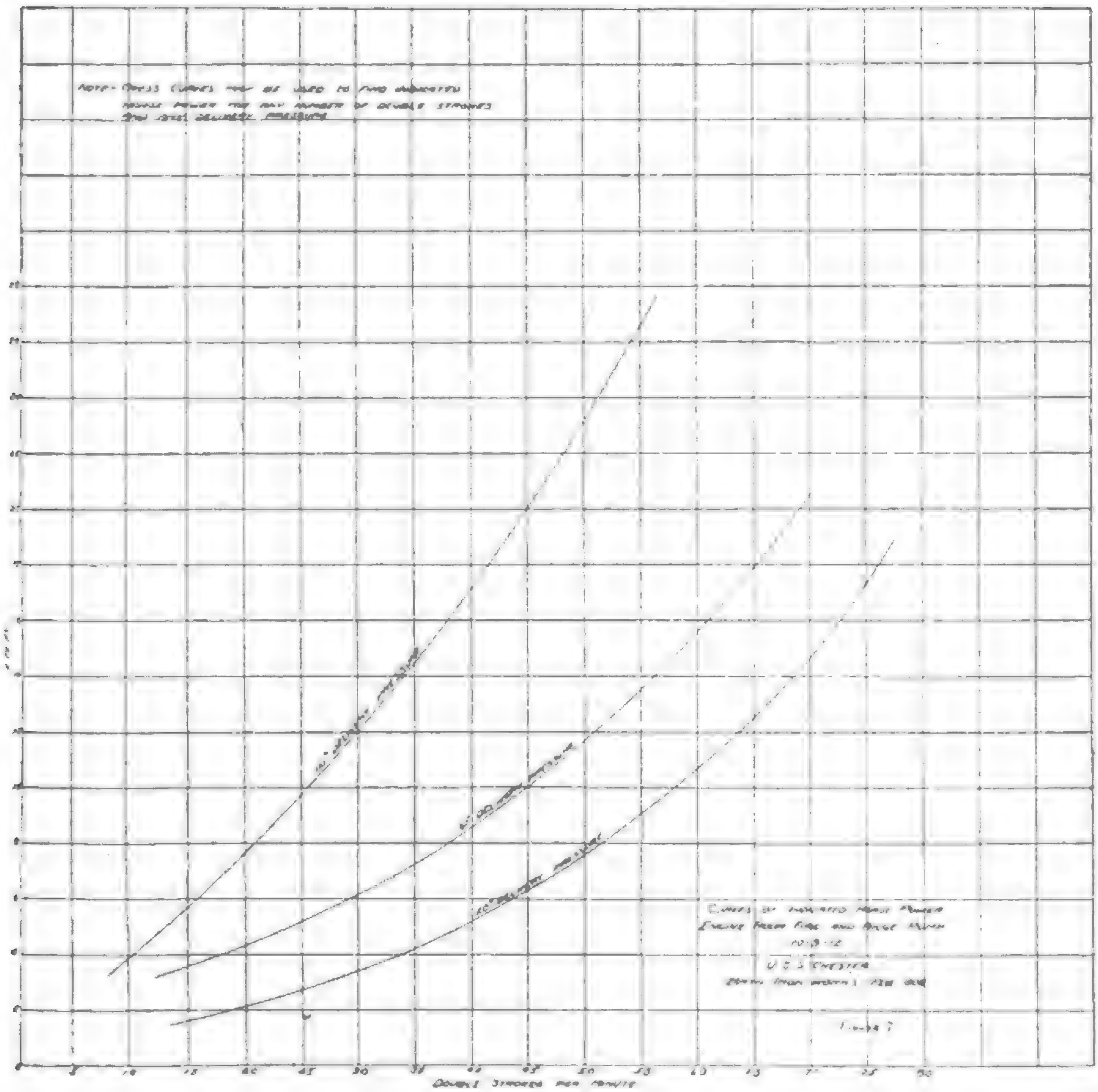

RESERVE-FEED PUMP.

One Blake vertical, simplex, piston pump, $10 \times 9 \times 12$, is installed in the forward engine room, with suction pipes from reserve-feed water tanks, suction main and filling pipe from ship's side, and discharge to reserve-feed tanks and main feed tanks.

FIRE AND BILGE PUMPS.

Two main fire and bilge pumps are located, one in each engine room. These pumps are vertical, simplex, piston pumps, $10 \times 9 \times 12$, of Blake type, with suctions from sea, engine-room drainage and C. & R. drainage manifolds, and with discharges to fire main, overboard and to hose connections.

There are three other fire and bilge pumps, one in each fireroom. These pumps are Blake, vertical, simplex, piston pumps, $12 \times 8 \times 12$, having suctions from fireroom floors in same compartment, from sea, from C. & R. drainage manifolds and from hose connections. They discharge into fire main, overboard in same compartment, into ash ejector and to hose connection. Curves of indicated horsepower are shown in Figs. 6 and 7.

PUMPS FOR EVAPORATING AND DISTILLING PLANT.

Of these there are two distiller circulating pumps, $10 \times 9 \times 12$, of Blake type, one evaporator feed pump, $4\frac{1}{2} \times 5 \times 6$, of Blake type, and one fresh-water pump, $4\frac{1}{2} \times 5 \times 6$, of Blake type. The latter is installed overhead in the trunk, where distillers and reservoir tank are located, the latter are on the bulkhead in evaporator room.

BOILERS.

There are twelve Normand water-tube boilers of the "intermediate" type in the vessel in three watertight compartments, four to each compartment. The following is the boiler data :

Designed working pressure, pounds	250
Test pressure, pounds	400
Ratio of grate surface to heating surface	1 to 46
Length of grates, feet and inches	$7-2\frac{1}{8}$
Width of grates, feet and inches	$8-0\frac{7}{8}$
Per cent. of air space in grates	49
External height, feet and inches	$12-5\frac{5}{8}$
length, feet and inches	$11-6\frac{5}{8}$
width, feet and inches	11-4
Number of furnaces	1
Grate surface, square feet	58
Heating surface, square feet	2,670
Total grate surface, square feet	696
heating surface, square feet	32,040
Weight of boiler, with water, tons	19,675
Boiler tubes	cold-drawn seamless steel.
Number of tubes each boiler	986, No. 10 B.W.G., O.D. $1\frac{3}{8}$ inches, lengths vary for each row.
Mean height of smoke pipes above grates, feet	63.25
Diameter of smoke pipes, inches	72

The forward and after smoke stacks have two boilers each, and the two middle stacks four boilers each.

Steam gauges on boilers are connected to the water drums.

STEAM PIPING.

The main steam line is arranged in two systems, one on each side of the ship. The branch from each boiler is 5 inches in diameter, and the main steam pipes, which are 5 inches in diameter at the forward boilers, increase in diameter at each successive connection from boilers to 7, 9, 10, 11 and 12 inches, respectively, the last diameter continuing to the handling platform in its respective engine room. There is a stop valve in each main steam pipe forward of the connections from boilers in the after and middle firerooms. Abaft the forward engine-room bulkhead there is a 9-inch cross-connection pipe between the main steam pipes on each side of the ship. An auxiliary steam line is installed, and this line has cross-connection to main steam line in the forward engine room. The auxiliary exhaust line is used on feed heaters and on the steam-gland system. The usual joints, drains, etc., are fitted.

FEED SYSTEM.

A suction main leads aft, gradually increasing in size, from the forward fireroom auxiliary feed pump to the feed tanks in each engine room. From this suction main, branches lead to non-return screw-top valves on engine-room main and fireroom auxiliary feed pumps. There are discharge pipes connecting to and by-passing the feed-water heater from each main feed pump. These pipes unite in a common main leading forward to the firerooms, with branches so arranged and valves so fitted that it may discharge into any or all of the boilers. Each branch has a gate valve, and leads to the main feed-check valve on the boiler. There are gate valves on the main feed pipes to keep the pressure off sections not in use or injured.

Each auxiliary feed pump discharges into an athwartship delivery pipe having branches so arranged that it may discharge into any or all of the boilers in its own compartment. Each branch has a gate valve, and leads to the auxiliary feed-check valve on a boiler. There are also gate valves for keeping pressure off sections not in use, and there is a connection in each fireroom between the athwartship delivery from auxiliary feed pumps and the main feed-discharge main.

WORKSHOP.

The workshop is located over the forward end of the forward engine room, and contains the following tools:

1 Fay & Scott extension gap lathe, 16-inch by 32-inch swing.

1 14-inch Flather screw-cutting lathe.

1 15-inch Hendy shaper.

1 Sibley & Ware 28-inch upright drill.

1 Brainerd universal milling machine, No. 14½.

1 Buffalo combined hand punch shears.

1 Blount No. 3 grinding machine.

1 Buffalo down-draft forge.

1 Workshop motor.

A blacksmith shop is located on the main deck with forge and anvil.

DRAINAGE SYSTEM.

The drainage system comprises three pipe lines, a 6½-inch main drain running between frames No. 52 and 100 with connections to five fire and bilge pumps and two main circulating pumps, a 4⅝-inch inner-bottom main running from frame No. 25 to frame No. 74, connecting to two fire and bilge pumps and with cross connections to main drain, and a 4⅝-inch after suction main with a connection to the main drain and the after fire and bilge pump. The main drain has direct connection with valve at connection to each fire and engine room. The inner-bottom main connects in a similar manner with the inner-bottom compartments and the forward bilges, and the after main with the after bilge. There are two handy-billy pumps located on berth deck, one forward and one aft, and have manifolds, numbered one and two respectively. Connections are taken from these manifolds for drainage and suction. A few of the small compartments have to be pumped out by handy-billy pump-hose suction. All compartment valves have label plates with compartment numbers on them.

FIRE SERVICE.

The fire main runs from frame No. 26 to frame No. 116 under the orlop deck, and is a 4½-inch pipe in the machinery spaces with reduction in size at the ends. The various fire plugs are supplied by risers. There are five fire and bilge pumps connected to the fire main, and the latter has a cross connection to the flushing main at frame No. 76.

FLUSHING SYSTEM.

A 5-inch flushing main runs under the main deck from frame No. 79 to No. 85, and is continued forward as a 2½-inch main to frame No. 44. The main has a direct connection to the distiller-circulating pump and a cross connection to the fire main. All bath rooms, wash rooms, closets and pantries have salt-water connections from the main.

FRESH-WATER SYSTEM.

Fresh water is supplied from the distillers, through the distiller pipe to the hold fresh-water tanks and also by direct connections to the firemen's and machinists' washrooms. Fresh water is also supplied to the hold fresh-water tanks through the fresh-water main by the water-boat connections at frame No. 76. Water is pumped from the hold fresh-water tanks as needed, by the electric pump, located on orlop deck at frame No. 21, into the gravity tank on top of the deck house. From there it runs by gravity into the fresh-water main which supplies by its connections all bath rooms, wash rooms and pantries.

CAPACITIES OF WATER TANKS AND COMPARTMENTS.

Main Fresh-water Tanks.

No.	Location. Frames.	Location. Deck.	Side of ship.	Capacity, gallons.	Capacity, pounds.
1	22–24	Hold	Starboard	1,600	13,333
2	24–26	Hold	Starboard	1,600	13,333
3	22–24	Hold	Port	1,600	13,333
4	24–26	Hold	Port	1,600	13,333
			Total,	6,400	53,332
5	Gravity tank*		......	1,000	8,333
			Grand total,	7,400	61,665

Auxiliary Fresh-water Tanks.

No.	Location, Deck.	Location, Frames.	Capacity, gallons.	Capacity, pounds.	Remarks.
1	Berth	48–49	100	833	P. O. and mach. washroom.
2	Berth	52–53	150	1,250	Firemen's washroom.
3	Berth	59–60	150	1,250	Firemen's washroom.
4	Berth	63–64	150	1,250	Firemen's washroom.
		Totals,	550	4,583	

Reserve Feed-water Compartments.

Compartment letter.	Tons, F.W.	Gallons, F.W.	Pounds, F.W.	Remarks.
C 96	37	8,605	71,680	Inner bottom.
C 97	30	8,065	67,200	Inner bottom.
C 98	28	7,530	62,720	Inner bottom.
C 99	24.5	6,578	54,880	Inner bottom.
Totals,		30,778	256,480	

* Located on top of deck house, over crew's galley.

Summary of Capacities for Fresh Water.

Items.	Gallons.	Pounds.
Main fresh-water tanks	6,400	53,332
Gravity tank	1,000	8,333
Auxiliary fresh-water tank	550	4,583
Total	7,950	66,248
Reserved feed water	30,778	256,480
Grand total	38,728	322,728

CAPACITIES OF INNER BOTTOMS AND TRIMMING TANKS (EXCLUSIVE OF FEED TANKS).

Compartment letter.	Location between frames	Capacities, in tons of F.W.
C 95	82-78	26
B 99	78-74	26
B 98	74-70	26
B 97	70-67	19
B 96	67-64	19
B 95	64-60	26
B 94	60-56	26.5
B 93	56-53	19
B 92	53-49	26
B 91	49-45	26

Trimming-tank Capacities.

A 1	Stern to 8	18
A 2	8-18	85
D 3	117 to stern	68

VENTILATION.

The ventilation comprises eight systems, numbered from forward aft. Each is supplied by a single electrically-driven fan, so located that the ducts cut the minimum number of important bulkheads. A supply system is provided for all quarters, storerooms, dynamo room and steering-engine room. An exhaust system is provided to closets. Natural exhausts are provided to dynamo and steering-engine rooms. Coal bunkers have natural supply and exhaust ventilation, the supply through coaling trunks and the exhaust through pipes connected to the uptakes with dampers fitted to all exhaust pipes near uptakes.

ELECTRIC PLANT.

There are three 32-kw. generating sets of 125 volts pressure at terminals. They are of the General Electric type, direct current, compound wound, multipolar. They are located in one dynamo room, on the platform deck just abaft the after engine room. Steam is supplied the dynamo engines direct from the auxiliary steam pipe, and an auxiliary condenser is provided for the exclusive use of these engines.

The dynamo engines are of the vertical, cross-compound, General Electric Company type, encased, and lubricated under pressure. The introduction of oil into the cylinders is guarded against by raised cylinders, and by plates on the tops of the enclosures in which there are soft-packing stuffing boxes for the rods and valve stems to work through.

There are three engines, one for each generator.

Diameter of H.P. cylinders, inches	7.5
L.P. cylinders, inches	12
Stroke, inches	8
Diameter of both piston rods, inches	$1\frac{3}{4}$
Revolutions per minute	400

The following motors are installed :

DECK WINCHES.

No. 1. Starboard forecastle, enclosed, compound-wound, 30 H.P.

No. 2. Port forecastle, enclosed, compound-wound, 30 H.P.

No. 3. Starboard main deck, enclosed compound-wound, 30 H.P.

No. 4. Port main deck, enclosed, compound-wound, 30 H.P.

VENTILATION.

No. 1. Berth deck, center line, open, shunt-wound, $1\frac{3}{4}$ H.P.
No. 2. Port orlop deck, open, shunt-wound, $1\frac{3}{4}$ H.P.
No. 3. Engine hatch, enclosed, shunt-wound, 5 H.P.
No. 4. Engine hatch, enclosed, shunt-wound, 5 H.P.

No. 5. Port berth deck, enclosed, shunt-wound, $1\frac{3}{4}$ H.P.
No. 6. Starboard deck, enclosed, shunt-wound, $1\frac{3}{4}$ H.P.
No. 7. Port orlop deck, open, shunt-wound, 5 H.P.
No. 8. Starboard orlop deck, open, shunt-wound, $1\frac{3}{4}$ H.P.

FRESH-WATER PUMP.

No. 1. Port orlop deck, enclosed, shunt-wound, $1\frac{1}{2}$ H.P.

In addition to the above there are also:

One 2-H.P. shunt-wound motor for dough-mixer;
One $\frac{3}{4}$-H.P. shunt-wound motor for potato-peeler;
One 10-H.P. shunt-wound motor for workshop;
One 1-H.P. shunt-wound motor for dish-washer;
Six $\frac{1}{4}$-H.P. portable ventilating sets;
Thirty $\frac{1}{12}$-H.P. desk and bracket fans;
Six $\frac{1}{8}$-H.P. bracket fans;
and others.

On the lighting circuit there are 640 sixteen-candlepower incandescent lights, 22 arc-lights, two sixty-inch searchlights of about 42,000 candlepower each, one night-signal set, two truck lights and two diving lanterns. The wiring is on the two-wire feeder system. The wiring is open insulation except on main, forecastle, platform and hold decks.

INTERIOR COMMUNICATIONS.

A complete central-station system of telephones is installed, there being 18 telephones. In addition, there are 35 lines of voice pipes. The telephones are a special type of loud-speaking instrument made by the Cory Co. With these instruments three wires are required for each instrument. Instruments exposed to moisture or weather are of the water-tight type. Two ear pieces are fitted, and they are expected to work satisfactorily in exposed places in high winds.

BOATS.

The ship has one 28-foot steam launch, one 33-foot sailing launch, two 30-foot cutters, one 30-foot whaleboat, one 30-foot gig-whaleboat, and one 14-foot dinghy.

ANCHORS.

The following anchors are supplied :

No.	Weight, lbs.	Type.	Stowage position.
1	7,500	Bower	Hawse pipe.
2	7,500	Bower	Hawse pipe.
3	7,500	Sheet	Billboard, port side.
4	3,020	Stern	Main deck, center line, aft.
5	1,540	Stream	Main deck, center line, aft.
6	761	Kedge	Forecastle, center line.
7	402	Kedge	Forecastle, center line.

PERFORMANCE.

FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressure.

	Starboard.	Port.
Mean steam pressure at engines, pounds	242.4	246.0
In main H.P. turbine (per gauge)	237.0	240.0
2d I.P. cruising turbine (absolute)	237.0	240.0
L.P. turbine (absolute)	30.2	29.9
Vacuum in condensers, inches of mercury, mean	28.9	28.3

Temperatures. (Average of one-half hourly observations.)

Injection, degrees	37.6	36.6
Discharge, degrees	73.0	83.6
Hotwell, degrees	78.2	96.0
Feed water, degrees	222.4	206.0
Engine room, working platform, degrees	51.5	59.0
Firerooms, working level, degrees	42.6	
Smoke stacks, average, degrees	848.0	

Revolutions, or double strokes, per minute. (Average of one-half hourly observations.)

Average revolutions, main engines, per minute	616.7	611.92
Pumps, main air	26.0	24.0
circulating	201.0	170.0
feeds, d.s., per minute	46.0	54.0
Dynamo engines	400.0	
Blower engines	349.8	
Speed of ship, in knots per hour	26.522	
Slip of propeller, in per cent. of its own speed based on mean pitch. Shafts are numbered from starboard to port.	(1) 25.71 (2) 25.99 (3) 26.18 (4) 24.34	
Air pressure in firerooms, in inches of water, mean	2.74	

Indicated Horsepower.

Air, circulating and feed pumps, main	328
All other auxiliaries	235

Coal.

Kind and quality used on trial	Pocahontas, hand picked.
Pounds, per hour, main and auxiliary engines, during trial,	38,332
of coal per square foot of grate surface, per hour,	55.08

TWENTY-FOUR HOURS' OFFICIAL TRIAL AT TWENTY-TWO AND ONE-HALF KNOTS.

Steam Pressure.

	Starboard.	*Port.*
Mean steam pressure at engines, pounds	230.0	
In I.P. cruising turbine, gauge	...	192.0
main H.P. turbine, gauge	96.0	93.0
L.P. turbine, absolute	15.0	13.8
Vacuum, in inches	28.3	29.5

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	36.0	36.0
Discharge, degrees	63.0	59.0
Hotwell, degrees	74.0	70.0
Feed water, degrees	182.0	205.0
Engine room, working platform, degrees	...	68.0
Firerooms, working level, degrees	54.0	...
Smoke stacks, average, degrees	629.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	459.71	486.97
Pumps, main air	19.7	21.4
circulating	143.0	156.0
feed, d.s., per minute	28.7	22.5
Dynamo engines	400.0	
Blower engines	180.3	
Speed of ship, in knots per hour	22.782	
Slip of propeller, in per cent. of its own speed, based on mean pitch. Shafts are numbered from starboard to port.	(1) 15.66 (2) 16.94 (3) 26.08 (4) 15.15	
Air pressure in firerooms, in inches of water, mean	0.7	

Coal.

Kind and quality used on trial	Pocahontas, run of mine.
Pounds per hour, main and auxiliary engines, during trial,	18,063
Knots per ton of coal	2.82
Pounds of coal per square foot of grate surface, per hour...	25.95

TWENTY-FOUR HOURS' OFFICIAL TRIAL AT 12 KNOTS.

Steam Pressures.

	Starboard.	Port.
Mean steam pressure in engine room	148.0	
In H.P. cruising turbine (gauge)	77.3	
I.P. cruising turbine (gauge)	...	34.6
main H.P. turbine (gauge)	8.0	6.8
L.P. turbine (absolute)	3.3	3.4
Vacuum, in inches	28.4	28.6

Temperatures. (*Average of one-half hourly observations.*)

Smoke stacks, average, degrees	566

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	254.09	245.29
Pumps, main air	8.6	11.5
circulating	109.4	113.4
feed, d.s., per minute	10.0	...
Dynamo engines	400	
Speed of ship, in knots per hour	12.2	
Slip of propeller, in per cent. of its own speed, based on mean pitch. Shafts are numbered from starboard to port.	(1) 12.21 (2) 24.66 (3) 19.59 (4) 12.08	

Coal.

Kind and quality used on trial	Pocahontas, run of mine.
Pounds per hour, main and auxiliary engines, during trial	4,091
Knots per ton of coal	6.68

Deduced Data.

Pounds of coal per square foot of grate surface per hour	17.63

NOTE.—The horsepower on these trials was taken with the Denny-Johnson torsion meter made especially for the vessel. Unfortunately this meter did not give results within reason. The apparatus was installed as shown by the Figure. All parts were very carefully adjusted and were examined during and

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after the trial to see that nothing had become loose. Also after the trial the two screws on each side of the vessel were alternately towed by the screws of the other side and allowed to revolve, giving the zero era of the machine, which was found to be *nil*. The observations were taken and checked by three different observers. After the experiments were over the meters were sent to the New York yard and tested there. It was found that two of them gave accurate results except at certain points where the wires were broken. The other two did not give reliable results. On examining the recording box carefully it was found that the rheostat coils of these two meters were broken and that various wires in the cable were also broken. The shafts varied so much in horsepower that it was impossible to calculate the horsepower with any degree of accuracy from the results of the two meters that worked satisfactorily.—EDITOR.

A PRACTICAL COMPARISON OF THE ADVANTAGES OF HIGHER CYLINDER RATIOS.

By Second Lieutenant of Engineers C. S. Root,
U. S. R. C. S., Member.

An examination of the cylinder diameters of naval engines will show cylinder ratios varying from 1 : 4.75 to 1 : 11.2 in *triple*-expansion engines of ships of war now in commission. This seems to point to a decided difference of opinion among naval engineers in regard to these ratios, and for this reason it is thought that the following account of two moderately long runs of the same vessel with different cylinder ratios may be of interest.

Passed Assistant Engineer E. T. Warburton, U. S. N., in the Journal of the American Society of Naval Engineers (Vol. IX), describes a trans-Atlantic run of the U. S. Steamer *Bancroft* from which the following is taken :

"The *Bancroft* was docked and refitted in September (1896), at the Navy Yard, New York, in ten days, for a cruise on the European station. * * * The *Bancroft* left Tompkinsville, Staten Island, N. Y., September 15, 1896, using both boilers, and arrived at Fayal, Azores, September 25. The dynamo was run about twelve hours, and about 300 gallons of water distilled every day. The vessel started with about 160 tons of bituminous coal on board. Distance steamed, 2,133 nautical miles ; time, 10 days 1 hour, or 10.04 days ; average speed, 8.85 knots ; average revolutions per minute, 124 ; coal used for all purposes, 102.69 tons ; coal per day 10.22 tons ; miles per ton of coal, 20.77. There remained in the bunkers 57.5 tons.

"Left Fayal September 28 and arrived at Gibraltar Octo-

ber 4. Strong head winds were encountered for the greater part of the distance. Distance steamed, 1,136 nautical miles: time, 6 days 3.75 hours, or 6.16 days; average speed, 7.69 knots; average revolutions per minute, 129.2; coal used for all purposes, 59.33 tons; coal per day, 9.63 tons; miles per per ton of coal, 19.14.

"Left Gibraltar October 6, and arrived Smyrna, Asia Minor, October 15. Distance steamed, 1,631 nautical miles.

"The coal obtained at Gibraltar was of such very inferior quality that the daily consumption necessarily increased.

"The trip from Tompkinsville to Smyrna (4,900 nautical miles) in 29.5 days, including stoppage of 2½ days at Fayal and 2 days at Gibraltar, at an average speed of 8.25 knots and an average daily coal consumption of 10.3 tons, is not a bad showing for this little vessel. * * *"

In the run described the vessel was equipped with two gunboat or low cylindrical boilers having 2-inch tubes. The total heating surface was 2,686 square feet and the grate surface 87.75 square feet. Her twin-screw, triple-expansion engines had cylinders 13½, 21 and 31 inches diameter and 20 inches stroke; the maximum designed working pressure being 160 pounds per square inch above the atmosphere.

In January, 1906, this vessel was transferred to the U. S. Revenue Cutter Service and her name changed to *Itasca*. During the following winter she was given a thorough overhauling and partial rebuilding. Water-tube boilers of the Babcock & Wilcox type, with 2-inch tubes, were installed. The boilers have a total heating surface of 3,825 square feet and a grate surface of 85 square feet. The matter of cylinder ratios was carefully gone over. New cylinders were designed to give a maximum card factor and minimum terminal pressure while maintaining the same referred M.E.P. that obtained in the old arrangement. The most suitable diameters were found to be 12 and 19 inches for the H.P. and M.P. cylinders. The L.P. cylinders were not changed. The "main-engine" auxiliaries, which included an independent, twin-cylinder, single-acting air pump, remained as before, but a larger elec-

tric generating set was installed, as was also a larger fan for forced draft and ventilation. A feed-water heater was added to her equipment and the maximum steam pressure raised to 215 pounds per square inch above the atmosphere. The propellers remained as before, and the vessel was ballasted to bring her down to her original displacement.

After the trial trips the vessel was taken to the Revenue Cutter Service Yard at Arundel Cove, Md., and hurriedly equipped for sea. She left there on July 20th, 1907, and called at New York, N. Y., and New London, Conn. She coaled at the latter place, and, leaving there on July 28, arrived at Ponta Delgada, Azores, August 7. The data obtained on this part of the voyage were unreliable, for reasons which it is not necessary to enumerate here, and these data will not be included in the figures used hereafter. The *Itasca* left Ponta Delgada, August 9, called at Gibraltar, Marseilles, Naples, Algiers, Funchal (Maderia), and arrived at St. Thomas, Danish West Indies, September 27. Total running time, 765.6 hours (31.9 days). Total distance steamed, 6,817 nautical miles. Total coal consumed for all purposes, 314.5 tons. Average steam pressure, 152 pounds per square inch. An average of 700 gallons of water was distilled every day. The coal obtained at Algiers was of the poorest quality, and it was difficult, at times, to maintain the low speed fixed for the voyage. This coal lasted for upwards of two thousand miles.

The *Bancroft* had strong head winds from the Azores to Gibraltar, and the *Itasca* encountered a gale in the Gulf of Lyons. On each voyage the vessel was handicapped by bad coal for portions of the run. While the *Itasca* distilled more water per day than the *Bancroft*, this was more than balanced by the feed heater. The weather during both runs was uniformly good, except as noted above.

Here we have two long runs at low speeds with practically no change in the vessel, except in the H.P. and M.P. cylinders of the main engines and the addition of a heater, for which a definite allowance can be made. The conditions for comparison seem to be almost as favorable as could be desired.

To sum up the two voyages, we have :

	Bancroft.	*Itasca.*
Ratio of the net piston areas	1:2.4:5.3	1:2.5:6.8
Grate surface, square feet	87.75	85.0
Time out of drydock at beginning of voyage, months,	0	2
Total distance, nautical miles	4,900	6,817
Average speed, knots per hour	8.25	8.9
Average coal consumption, tons per day	10.3	9.86
Water distilled, gallons per day	300	700
Dynamo in operation, hours per day	12	12

In an article published in Vol. XV of this journal, Lieut. D. S. Mahony, U. S. N., has shown that, if the relation between coal consumption and speed follows any law, it is probably as follows:

If rectangular coördinates be used, speed in knots per hour plotted as abscissae and coal consumption in tons per day as ordinates, the curve thus found will differ very little, if at all, from a curve satisfying the equation $y = c + kx^2$. From data in Lieut. Mahony's article is deduced the fact that the actual plotted values of the coal-speed curves of a large number of vessels of the United States Navy did not vary, on an average, from the form $y = c + kx^2$ by more than 3 per cent., the maximum variation being 6.4.

This form of curve will, therefore, be used in making the comparison.

Let $y =$ the coal consumption in tons per day for all purposes at the speed s.

$c =$ the coal consumption in tons per day for all purposes at zero speed, *i. e.*, with all the usual auxiliaries in operation and the engines kept well "warmed up," making, say, 400 revolutions per hour.

$k =$ a constant which must be computed for each vessel.

$s =$ the speed of the vessel in knots per hour.

Then will $y = c + ks^2$.

In the case of the 4,900-mile run of the *Bancroft* we have: $y = 10.3$, $c = 3$, $s = 8.25$. Hence, $y = 3 + .1072\, s^2$. For the 6,817-mile run of the *Itasca*: $y = 9.86$, $c = 3$, $s = 8.9$. Therefore, $y = 3 + .0866\, s^2$.

The value of c was taken from the naval records. These

curves have been plotted and are shown on the accompanying diagram. The difference in coal consumption is seen to be in favor of the later arrangement of machinery, and at 9 knots is equal to $(3 + .1072 \times 9^2) - (3 + .0866 \times 9^2) = 1.67$ tons per day.

The feed heater raised the temperature of the feed 80 degrees Fahrenheit, and, taking the evaporation as 8 pounds of water per pound of coal—which seems ample in view of the quality of coal used throughout the voyage—a simple calculation will show that about one-third of the 1.67 tons of coal saved per day was due to the heater. The remainder of the saving can not be accounted for unless it be credited to the superior economy of the new cylinder ratio of the propelling engines.

The following facts in regard to this particular steam plant are brought out by the above comparison and the trial data of the vessel published in the August, 1907, issue of this journal.

1. The engines with the larger cylinder ratios developed higher power on a slightly smaller grate surface.

2. They have shown greater economy at low speeds.

3. The weight of the engines is a little less, due to the reduction of the H.P. and M.P. cylinder diameters.

The substantial increase in economy due to a small increase in cylinder ratios and steam pressures is again illustrated in the case of the U. S. steamers *Newport* and *Annapolis*. Their hulls are similar, as shown below, both vessels being composite and sheathed with copper.

	Newport.	*Annapolis.*
Length between perpendiculars, feet	167.75	168.0
Beam, molded, feet	36	36
Mean draught, feet	12	12
Displacement, tons	1,010	1,017
Area of immersed midship section, square feet	354	357
Block coefficient	.482	.49
Midship section coefficient	.82	.82
Load water line coefficient	.743	.74

Their engines are as follows:

	Newport. Jacketed.	*Annapolis.* Not jacketed.
Cylinders, diameter, inches	13½, 23½, 36	15, 24½, 40
Stroke of pistons, inches	30	28
Ratio of H.P. to L.P., by net piston areas	1 : 5.67	1 : 7.27

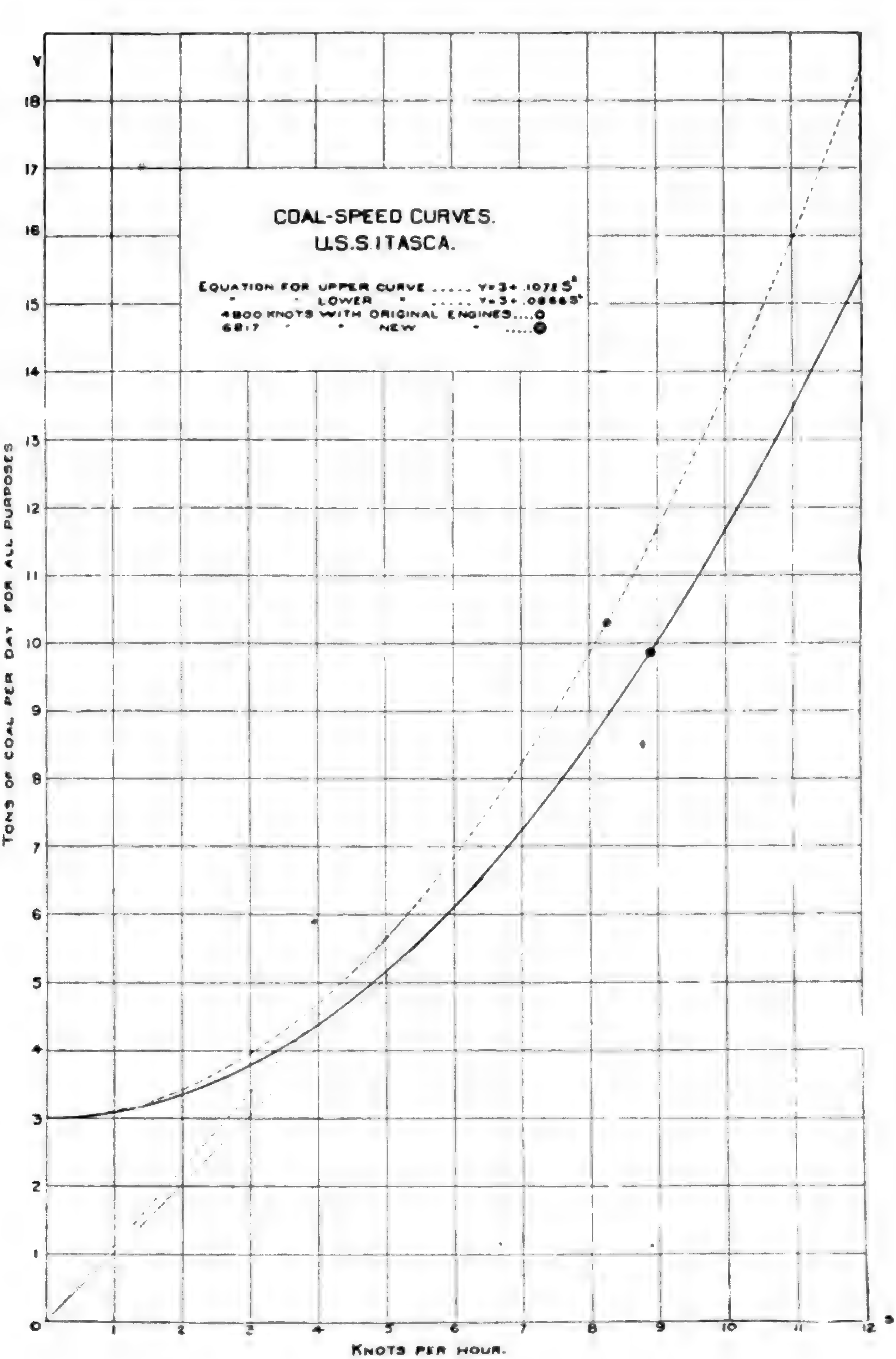
The following data are from cards taken on the official trials:

	Newport.	*Annapolis.*
Pressure at boilers, pounds per square inch, gauge	177	224
M.E.P. referred to L.P. cylinders	42.8	46.58
Piston speed, feet per minute	684.25	686
Indicated horsepower	904	1,217
Terminal pressure of the pv curve from combined diagram,	20.3	18.63
Water per I.H.P., per hour	15.39	13.33

The superior efficiency of the machinery of the *Annapolis* as shown by the water rate above was afterwards maintained in service. Another point indicated by these data is, that had the *Annapolis* been fitted with a 36-inch L.P. cylinder, the cylinder ratios remaining as before, they would have developed power equal to the *Newport* and must have weighed less. These results check with the runs of the *Bancroft* and *Itasca* described above.

Data, from runs made at low speeds, and selected because of similarity of conditions, are given below:

	Newport.	*Annapolis.*
Date	July, 1908.	Aug. & Sep., '08.
Months out of drydock	7	16
Fore and aft sail set, per cent. of time	50	50
Bunker capacity, tons	232	222
Full-load displacement, tons	1,128	1,116
Duration of the run, hours	156	257.3
Speed, in knots	8.1	8.2
Knots per ton of coal	17.4	26.97
Endurance, days	19	30.4
knots	3,722	5,987


COAL-SPEED CURVES.
U.S.S. ITASCA.
EQUATION FOR UPPER CURVE ..... $Y=3+.1072S^2$
" " LOWER " ..... $Y=3+.0866S^2$
4800 KNOTS WITH ORIGINAL ENGINES....O
6817 " " NEW " .....⊙
TONS OF COAL PER DAY FOR ALL PURPOSES
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MODERN ARMOR AND ITS ATTACK.*

By Captain T. J. Tresidder, C. M. G.

The invitation of the Council of this Institution to prepare a paper on the above subject was not accepted by the writer without considerable hesitation, in view of the fact that the material at disposal from most of the possible standpoints was already pretty well used up. A very able paper by Mr. C. E. Ellis, read before the Institution in 1894, brought the history of armor up to the commencement of the period of Harveyed plates; and three years later, an elaborate treatise was published in Italy in the "Rivista Marittima." It is true that the present type of plate was then too young to be included, but several papers have appeared in this country and elsewhere in recent years in which the historical and manufacturing sides of the subject have been more or less exhaustively dealt with and brought up to date.

One point of view, however, appeared still to afford room for an article, namely, the theoretical and analytical; so that has been adopted for the present notes, which, it will be understood, are a mere record of individual opinions based on an experience of much less extent than that of some who may read them.

In looking over some old reports of armor-plate trials, the writer was struck by the frequent repetition of "No penetration" in the column headed "Effect on the Plate." This, of course, meant "No perforation;" but the phrase, seeing that it was used not by tyros but by gunnery experts, suggested that, even in a paper intended for submission to a body of scientific men, it might not be out of place to emphasize the

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*Paper read before the Institution of Naval Architects, April 8, 1908.

necessity for attaching precise meanings to the few words constituting the special vocabulary of ballistics.

When two bodies come into collision, "no penetration" is as impossible as perpetual motion. The hardest plate made cannot arrest a drifting snowflake without suffering penetration; for the flake has "work"—in however minute a quantity—stored up in it, and to stop it an equal amount of work must be done by the plate.

What are the agencies the plate can command for doing this work? First, there is F, the mean pressure of the reaction it exerts on the flake.* But pressure alone, even if gigantic, can do no work; it must have distance to act through; and, since the whole plate cannot be expected to move under the circumstances, this necessary distance S can only be obtained by penetration. FS represents the work the plate must do, and FS must equal the work stored in the moving flake, which, though ridiculously small, is not zero. Consequently FS cannot be zero, as would be the case if either F or S separately were zero, which proves the statement.

The word penetration must not be taken to have only the limited meaning of permanent penetration. If penetration does not strain the material of a plate beyond its elastic limit it will be temporary only. It may leave no traces; but, if there has been a collision of any kind, it will have occurred all the same. Penetration is incomplete perforation; perforation is complete penetration. The reference to the snowflake and armor plate is redeemed from triviality by the fact that it forms a striking illustration of the fundamental principle of armor resistance.

As the weapon of the projectile is WV^2, so that of the plate † is FS. It has no other; and all the variations that

* The symbols used throughout this paper and its appendices have the following meaning:

W = weight of projectile, in pounds.
D = its caliber, in inches.
L = its length, in inches.
F = the mean value over the distance of arrest of the end-on pressure, in tons.
t = thickness of plate, in inches.
V = striking velocity in feet per second.
S = distance in which projectile is brought to rest, in inches

† This is a law which governs all plates alike, from the impossible plate of infinite hardness whose F is infinity and S zero, to the impossible plate of infinite softness whose F is zero and S infinity.

are possible in armor resistance are variations of these two factors, although, for any given value of F, considerable variation is also possible in the amount of maximum pressure and the instant of its development.

F, being the mean mutual pressure between projectile and plate, can only increase with the energy of the former up to the maximum capacity of the material of the latter. The stronger that material is the larger can $F S$ be (and, therefore, the higher the amount of WV^2 that can be resisted) for a fixed value of S. On the other hand, the less rigid the plate is, and the more deformation it can undergo without rupture, the greater can $F S$ be (and, therefore, the higher the amount of WV^2 that can be withstood) for a fixed value of F. This constitutes the general principle of which we may now proceed to examine the details.

The resistance of armor plates to perforation by projectiles may be divided into three classes:

(*a*) Rigid and concentrated.
(*b*) Yielding and distributed.
(*c*) Combination of (*a*) and (*b*).

In class (*a*) the molecules of the plate very strongly resist alteration of their relative position, but are incapable of retaining their inter-cohesion when that relative position is forcibly changed. Steel plates that are hard throughout are examples of this class. They present a high resistance per unit of area actually attacked, but do not distribute the work of resistance to perforation* much beyond that area. Their FS relies principally on the F element.

Plates that are tough throughout are examples of class (*b*). These offer less resistance per unit of area actually attacked, but utilize very largely the resistance of the metal outside that area. In this class of material the molecules less strongly

* Resistance to "racking" is altogether a different thing. It used to be as important as resistance to perforation, but improvements in armor have rendered plates practically secure from failure under "racking" attack, so it need not be taken into account in the discussion of armor resistance proper. It must not, however, be lost sight of in the general design of armored structures, for it may cause failure of the bolts, etc. The more a plate resists with its F factor the more will the bolts be strained in tension; the more reliance is placed on the S factor the more important is it that the bolts should be capable of suffering sudden bending and distortion without breaking.

resist alteration of their relative positions, but are capable of retaining their inter-cohesion when that relative position is forcibly changed to a substantial extent. Their *FS* relies largely on the *S* element. The essential difference between classes (*a*) and (*b*) is not one of strength, nor necessarily one of hardness, but one of structure. Class (*a*) materials must have a crystalline structure; those belonging to class (*b*) should have an amorphous one.

Consider the case of two plates of equal thickness, one a sample of class (*a*) having a breaking stress of 100 tons per square inch, and the other of class (*b*) with 50 tons per square inch; and suppose both to be incapable of cracking and to be normally attacked by the same unbreakable projectile at equal increasing velocities. Which will suffer perforation earliest? Probably the hard plate; for, although it can muster 100 tons per unit called upon, it calls upon so few units that the total force exerted by the shell divided by this number may exceed 100 tons before the same force divided by the larger number of units called upon by the soft plate exceeds 50 tons.

Moreover, all the work stored up in an unbreakable projectile has to be done on the plate, and must be balanced by the sum of the forces necessary to displace each displaced molecule of plate metal multiplied by the distance through which each force acts. Each molecule of the hard plate may take a double force to displace it, but the bulk of the force only acts through the distance necessary to produce rupture, and this will be quite a small distance with a hard plate, and a substantial distance with a soft one.

The best illustration of this principle is seen by the stopping of a cricket ball by a net. If, instead of a net, a fence of ½-inch pine were used to stop the ball, it is not impossible that a fast bowler might smash through it. Yet, comparing the materials, one would expect much more strength in ½-inch wood than in netting. The wood fails because it tries to stop the ball with very small self-displacement: its *F S* is nearly all *F*. The net succeeds because it accepts a large self-displacement; *S* plays the leading part in its *S F*.

So far, on the assumption that the projectile is unbreakable, the balance of advantages seems to lie with the soft plate, apart from the fact that it is not liable to crack, which the all-hard plate is. There are, however, one or two considerations which introduce a practical modification into this comparison. One is that it is not always convenient, and sometimes it is not possible, to permit the substantial deformation the capability of undergoing which, without rupture, is the feature of the soft plate. A more or less rigid resistance is essential, for instance, in the protective armor of many gun positions where quite a small deformation would jam the mounting and put the gun out of action. Under such circumstances an all-hard plate might find employment if we could make one that would not crack. Another modifying consideration is that the distribution of work and the material displacement on which class (*b*) relies take time, and, therefore, are less pronounced advantages when the projectile's energy is principally due to high velocity than when it is more the result of large weight.*

Modern face-hardened plates come under class (*c*). The hard layer adds to the general rigidity, but while by so doing it diminishes S, it is doubtful if it adds anything to F, although it very greatly increases the pressure at the first instant of impact when the point of the shell, if uncapped, is without lateral support. It alters the shape of the pressure diagram, so to speak, without adding anything to its area. (See Figs. 12, 14 and 15.) As the hard layer does not involve liability to cracking of the whole plate, the hard-faced plate (even against unbreakable shells) has advantages for shields whose substantial deformation would be fatal. Seeing that class (*b*) plates, however, can be made to combine high values of both F and S, there would probably be but little scope for hard-faced plates if projectiles could not be broken; but against

* A 2.24-inch shell of 6 pounds at 3,000 f.s. and a 12-inch shell of 850 pounds of 583 f.s. have equal energy per inch circumference. A hard-faced thin plate would give good results against the former although small uncapped projectiles are less easily pulverized on a hard face than large ones), but would make a very poor show against the latter. With a strong, tough, homogeneous plate, erected so that it could accept deformation, the difference would be just the other way.

breakable shells they have a great advantage in the fact above alluded to, that they introduce high-stress intensity at the first moment of impact when the shell's delicate point, if uncapped, is very weak. High-stress intensity that is reached at any later stage of impact does not find the point without lateral support, which is the reason it is so important that, in a plate designed to break projectiles there should be no soft layer whatever in front of the hard one.* It was owing to their power of breaking projectiles that hard-faced plates held the field before the general introduction of caps; and, although since that time they continue to hold the field, it is principally to impose upon an enemy the inconvenience and expense of capping all his A. P. shell.

Caps† play such an important part in the present-day attack of armor that it is desirable to devote some space to their discussion. Let us first consider the manner in which an uncapped pointed projectile behaves on impact with a hard face, and then pass on to discuss the purpose a cap serves, and how it serves it.

At the moment of first impact of an uncapped pointed projectile of given weight and caliber on a hard face, an "end-on" pressure, dependent directly on the square of the velocity and inversely on the amount of yielding of the plate, is applied to its point. This pressure it will be strong enough to bear if V does not exceed a certain value, which may be called the first critical velocity. Up to this value of V the projectile needs no cap, because it is strong enough without one. All the work is done on‡ the plate, which receives an indent al-

* A case is remembered of a treated compound plate where the face had good punch-breaking hardness about $\frac{1}{16}$ inch below the surface, which was itself soft. It was perforated by projectiles; it would certainly have defeated if the thin soft layer (which helped the shell like a cap) had been removed.

† The idea of putting a cap on the point of a projectile to save it from fracture on impact with a hard face emanated originally from a British engineer officer, Captain (now Lieutenant-Colonel) English, in 1878. It was suggested by the behavior of a Palliser shot that had been fired against a compound plate accidentally erected with its soft side in front. Captain English designed the first cap that was ever tried, and it gave a successful result, but the matter was allowed to drop for some reason that has not officially transpired. The Russians took the idea up in 1894, and since that time the use of caps has extended and is now almost universal for projectiles intended to perforate hard-faced armor.

‡ The difference between "on" and "by" is important. All the work stored in a projectile must be done *by* the plate that stops it; but the amount done *on* the plate will be less than the whole by the quantity, if any, that is done on the projectile.

most as if had no hard face; this indent may amount to perforation if the plate is thin enough and well held up. The projectile should remain intact.

Immediately V is increasd beyond the first critical value (though it may be by the addition of only a single foot-second) matters undergo a radical change. The initial pressure reaches an amount in excess of the maximum than can be supported without fracture by the projectile's point, which consequently fails and involves the destruction of the whole shell. This, in flying to pieces, absorbs so large a portion of the whole work that it leaves but little to be done on the plate; so the latter suffers to a very small extent, and very much less than at the preceding lower velocity.

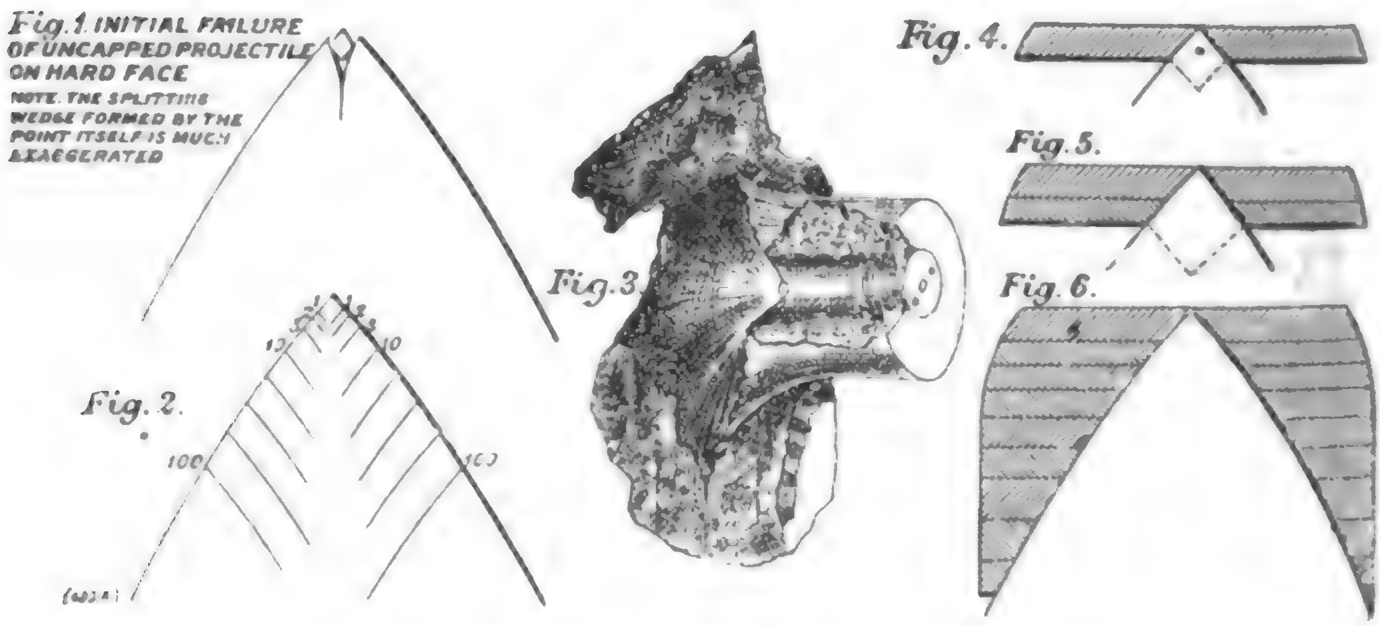
As the speed of attack is increased still further the wrecking of the projectile is more and more complete, and the amount of work absorbed by it increases also, but by no means in proportion to the increased total. More and more remains over, therefore, to be done on the plate, which accordingly suffers more and more till at last perforation is effected. This perforation is not in the form of a clean parallel hole, but a rough conical one of great size at the back, from which a large cone-shaped disc is smashed out.

The augmentation of velocity being still continued, another critical velocity—which may be called the third, and is an extremely high one—is eventually reached, when the projectile, though uncapped, is able to stand the initial compression stress, either because of the extra rigidity imparted to its molecules, or because of this combined with an actual reduction of pressure.* It then goes through unbroken and leaves a clean hole.

The nature of the uncapped projectile's failure between the first and third critical velocities may be confidently stated to be the following: A small piece of the extreme point in the form of a double-ended cone is driven back into the head and splits it like a wedge (Fig. 1). This initial split is succeeded

* The writer has a theory on this subject which he had intended for inclusion in these notes, but the intricacy of the argument rendered it impossible for a reasonably brief summary to do justice to it.

by numerous others following each other in the order of the numbers in Fig. 2, maintaining a direction approximately parallel to the rear surface of the originally formed double cone. The idea is that when the point is arrested it causes a surface of cleavage say at 1, 1 (Fig. 2); nevertheless, the point enters the plate and the shell is again arrested as at the points 2, 2, 3, 3, and so on, each time cleaving along a new conical surface, extremely near the previous one at first, and a little more widely spaced later on. The resulting conical laminæ thus intiated break up and fly tangentially to the plate as fast as they form, so that the rear part of the shell is "piled



up" on the front part, as in Fig. 3, which was sketched from an actual result.

It will be observed that the mischief originates close to the point, and that the fatal first wedge does its work by bursting laterally the portion of the head just behind it. If this portion were fitted with a reinforcing ring of adequate strength (Fig. 4), the wedge could not be driven back, and the point would be saved. A larger wedge, shown by dotted lines, would then try to burst the head further back, and another reinforcing ring would be required (Fig. 5). But the projectile is larger and stronger here, so the second ring need not be so strong as the first. Imagine this process repeated, of larger

and larger wedges counteracted by weaker and weaker rings, till a part of the head is reached where there is mass and strength enough to need no reinforcement. The system of rings is then like Fig. 6, and, if all the separate rings are united into one wide ring of varying thickness, the dotted line of Fig. 7 results, which shows a section of a Firth cap after

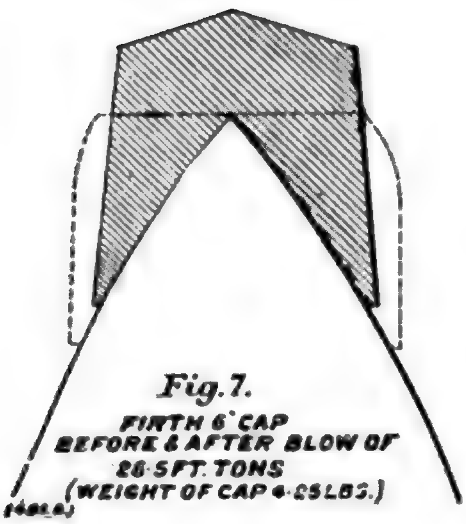


Fig. 7.
FIRTH 6" CAP
BEFORE & AFTER BLOW OF
26·5 FT. TONS
(WEIGHT OF CAP 4·25 LBS.)

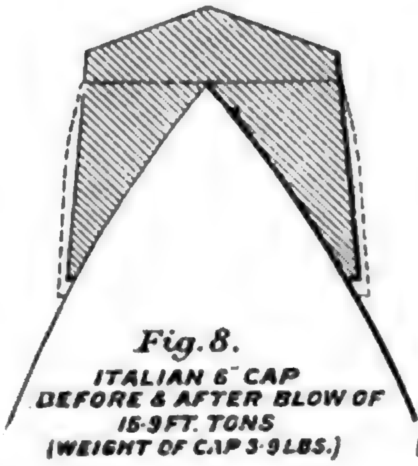


Fig. 8.
ITALIAN 6" CAP
BEFORE & AFTER BLOW OF
15·9 FT. TONS
(WEIGHT OF CAP 3·9 LBS.)

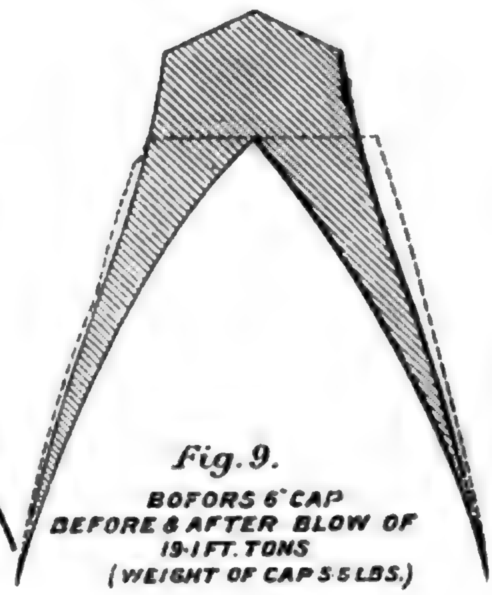


Fig. 9.
BOFORS 6" CAP
BEFORE & AFTER BLOW OF
19·1 FT. TONS
(WEIGHT OF CAP 5·5 LBS.)

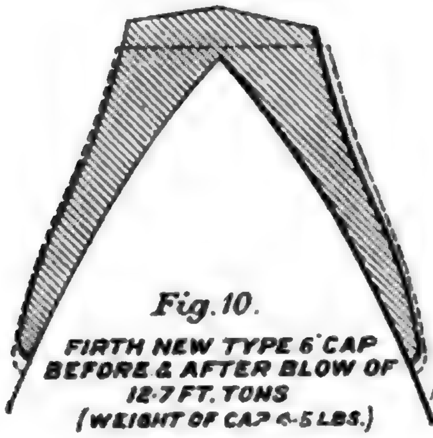


Fig. 10.
FIRTH NEW TYPE 6" CAP
BEFORE & AFTER BLOW OF
12·7 FT. TONS
(WEIGHT OF CAP 6·5 LBS.)

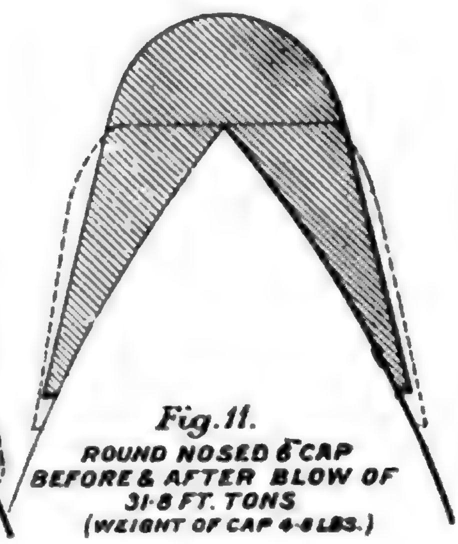


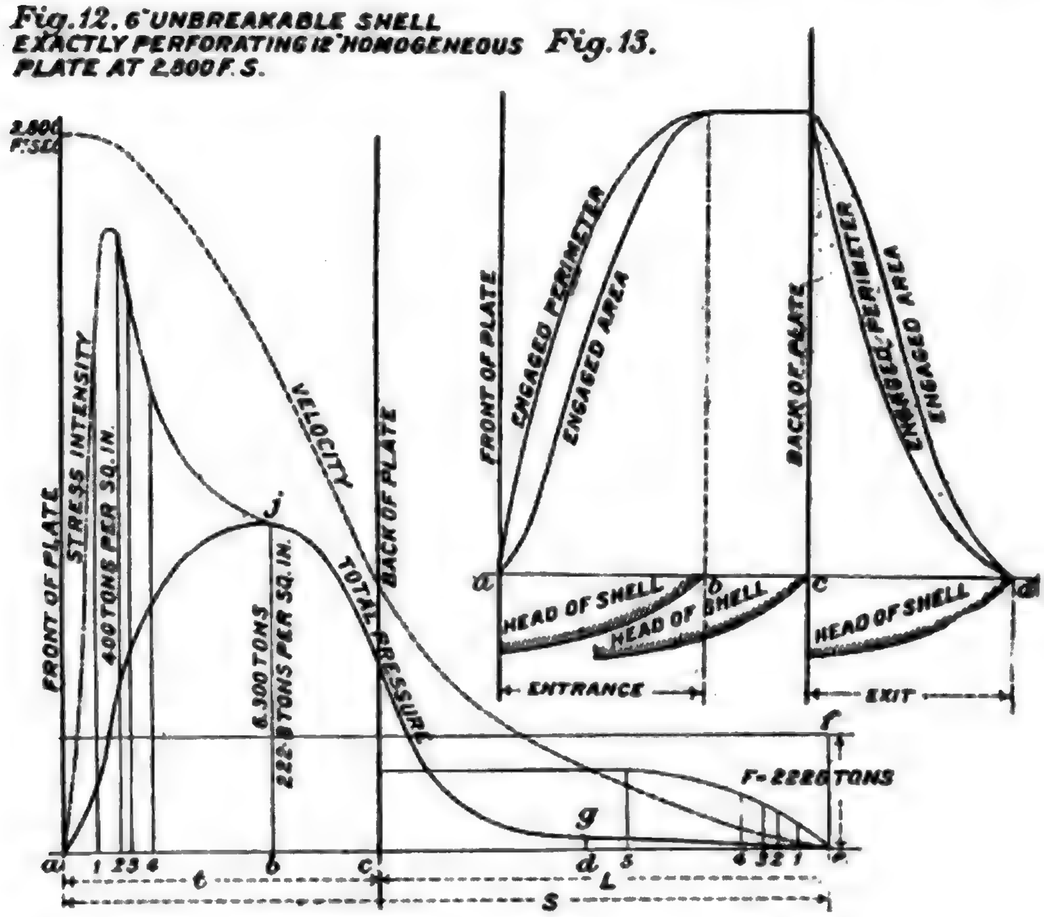
Fig. 11.
ROUND NOSED 6" CAP
BEFORE & AFTER BLOW OF
31·8 FT. TONS
(WEIGHT OF CAP 4·8 LBS.)

being experimentally crushed to the level of the shell's point by a single blow of 26.5 foot-tons. From this it will be seen that the main function of the cap is that of a series of reinforcing rings, whose thickness, and therefore strength, should be proportioned to the amount of reinforcement needed at each part. Figs. 8 to 11 show various other 6-inch caps before and

after being crushed by a single blow of energy proportioned to the cap's design.

Postponing for a moment the consideration of the design

Fig. 12. 6" UNBREAKABLE SHELL EXACTLY PERFORATING 12" HOMOGENEOUS PLATE AT 2,800 F.S. Fig. 13.



of the cap, it is important to note how its efficiency depends on the projectile having adequate velocity. Three critical velocities have been mentioned; the first being that which raises initial intensity of compression stress above the limit

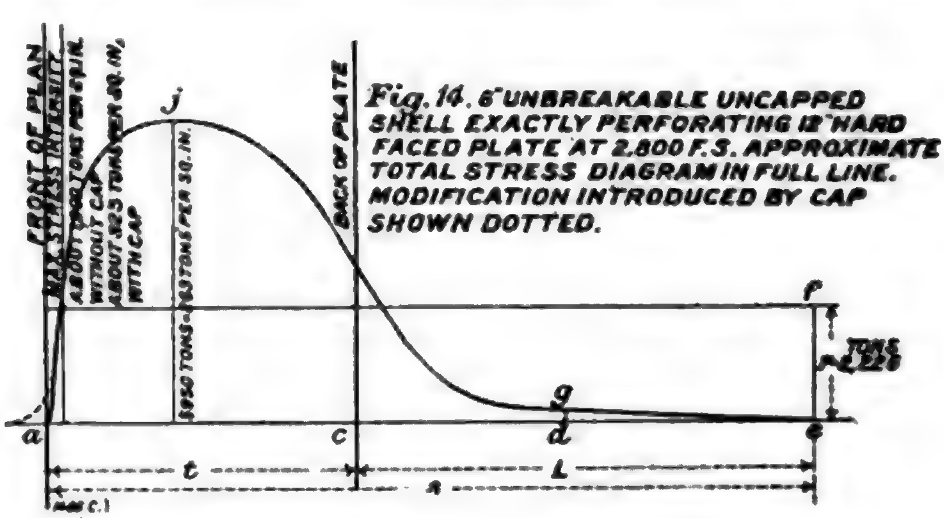


Fig. 14. 6" UNBREAKABLE UNCAPPED SHELL EXACTLY PERFORATING 12" HARD FACED PLATE AT 2,800 F.S. APPROXIMATE TOTAL STRESS DIAGRAM IN FULL LINE. MODIFICATION INTRODUCED BY CAP SHOWN DOTTED.

the uncapped point can stand, and the third that which, either by reducing initial pressure or by raising the strength of the shell, or both, enables the uncapped point to bear the compression stress it is subjected to. (A tallow candle, driven undeformed through a wooden board is an excellent illustration of the third critical velocity). Below the first and above

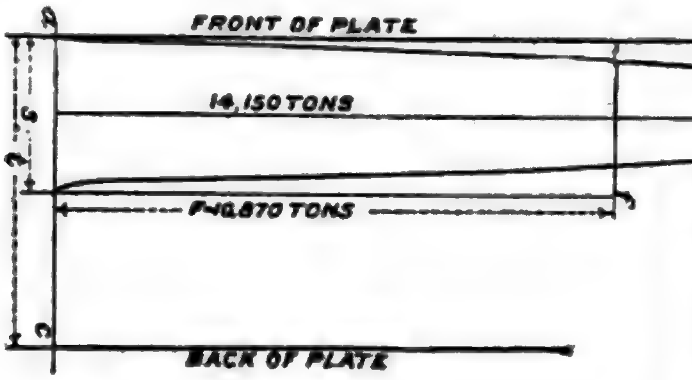
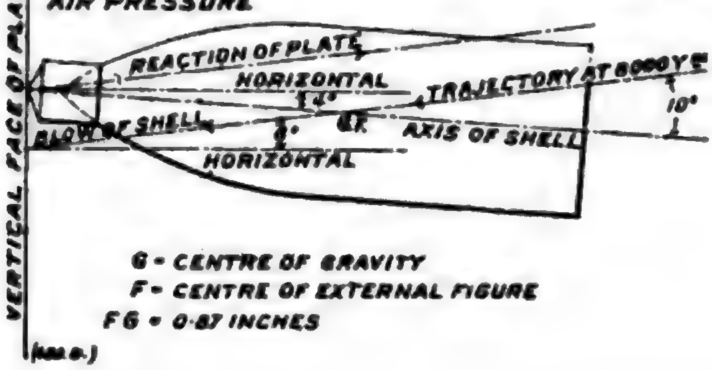


Fig. 15. UNCAPPED SHELL PULVERISED ON IMPACT WITH 12" HARDFACED PLATE AT 2000 F.S. PENETRATION

the third critical velocity the projectile needs no cap, because it is strong enough without one. The support afforded by the cap obviously depends on its resistance to stretching in the time available. The shorter that time the more power will be needed to make the cap stretch within the limit of it.

Fig. 16. IMPACT OF 12" SHELL AT 8000 YARDS ON VERTICAL ARMOUR, ASSUMING INFLUENCE OF GYROSTATIC ACTION TO PREVAIL OVER THAT OF AIR PRESSURE



The time concerned is inversely proportional to the striking velocity. Therefore the greater V is, the more reinforcement of lateral strength will the cap afford to the projectile; and, inversely, the smaller V is, the less efficient will the cap be. It is easy to see, then, that there must be a velocity which is

only just high enough to enable the cap to give adequate reinforcement. This may be called the second critical velocity.

Recapitulating, we may state that, in the attack of a hard-faced plate with increasing velocities—

The first critical velocity is the minimum value of V which raises initial intensity of compression stress beyond the limit the point of the uncapped projectile can bear without fracture.*

The second critical velocity is the minimum value of V which enables the cap to adequately reinforce the projectile's point so that it can bear a higher initial stress without fracture.*

The third critical velocity (much higher than the other two) is the minimum valve of V which enables the point of the uncapped projectile to again bear without fracture the stress intensity it is subjected to.

The third critical velocity undoubtedly exists, as otherwise a soft candle could not be driven undeformed through a wooden board,† the explanation of which phenomenon affords room for much interesting discussion. If there is nothing the matter with the plate this velocity may be expected to be a very high one.

The second critical velocity appears to lie, according to quality of plate and quality and design of projectile and cap, between 1,650 and 1,800 f.s.

The first critical velocity has been noted as high as 1,620 f.s. with a 4.7-inch Krupp shell and a 6-inch Harveyed plate; but against a modern Krupp plate with a proper depth of hardness it would probably be very much lower. If, then, a capped shell succeeds in perforating unbroken at 1,600 f.s., or

* The first and second critical velocities may in some cases overlap so that there may be no velocity high enough to break the uncapped projectile and yet at the same time low enough to render the cap inefficient. In such cases a capped projectile is saved from fracture of its point at all velocities. In other cases (dependent on quality of projectile, plate and cap) there may be a small range of velocities that are too high for the uncapped projectile to stand without fracture, and at the same time too low to render the cap efficient. In such cases the projectile will fail to hold together over this range of velocities whether capped or uncapped.

† This is not merely a reference to an old legend that all have heard of, but few have verified. Among the numerous experiments carried out for the purposes of this paper the "candle and board" legend was put to the test, and it was found that marked decrease of deformation in the candle attended moderate increases of velocity.

less, it does not follow, as is often argued, that that velocity is high enough to make the cap efficient; for, with an inferior plate, or a superior shell, it may be that it is low enough to make the cap unnecessary.

We may now consider the design of the cap and its effect upon results. Up till recently the writer held the opinion that the lateral reinforcing action of the cap, already referred to, was the only action of importance it performed. This opinion, however, he has now modified after further detailed study of the problem, very much assisted by the working out of stress diagrams. He still thinks that this reinforcing action, if in large quantity (as in the case of a substitute for a cap consisting of a large wrought-iron plate placed in front of a hard face), would not need supplementing in any way; but it is impossible to deny that it is supplemented in fact, whether it needs it or not.

When the cap and plate first come into collision a high stress intensity occurs for both. The questions that arise are: does the cap (1) yield to this by being flattened, as in Figs. 7 to 11, before the hard face of the plate is disintegrated; or (2) does inertia so support it (as in the case of the candle experiment) that it pierces the hard face without being deformed itself; or (3) do deformation of the cap and disintegration of the hard face go on simultaneously? The probably correct answer is that (1) occurs up to a certain velocity; then (3) as velocity increases; and finally (2) when velocity becomes very high indeed.

If the lowest velocity at which (3) begins exceeds practical fighting velocities, then the cap should be designed as a lateral reinforcer only. That is, it should have, to begin with, one of the forms of the crushed caps shown in Figs. 7 to 11, because it is wasteful of the shell's energy to call upon it to do this preliminary flattening which might better be done in the factory. More than this, the extra resistance to stretching from a state of rest the cap has in virtue of the inertia of its molecules is lost if the crushing is done against the plate, as just when their reinforcing action is called for these mole-

cules are already in rapid motion in the direction stretching gives them.

If, on the other hand, practical fighting velocities enable the cap to act as in (2), or even as in (3), then it should be sharp-pointed, in order to ensure the greatest amount of pressure concentration. The writer sees no theoretical justification for the obtuse-pointed design, and still less for a round-headed design, in either case.

To understand this matter thoroughly it is necessary to go back to the reason for using ogival-headed projectiles at all. Why was a sharp point ever given to an A.P. projectile? The answer is, to concentrate compression stress and give it high intensity, in the hope that the plate would yield thereto before the projectile did. This hope was realized at the commencement, when plates were soft and homogeneous. Then came the steel-faced compound plate which put up the standard of stress-intensity to more than the chilled cast iron projectile could stand.

The reply was the forged-steel shell which brought victory once more to the side of the attack. The defence retorted with the all-steel plate with super-carburized and chilled face, raising stress intensity again to a point at which the shell was the first to give way. Now the projectile gives battle with its nose swathed in a steel bandage to increase its power of bearing-stress intensity, and this expedient, for the time, at least, has restored its supremacy.

It will be seen, then, that from the first the shell has been the one to make power of bearing-stress intensity the issue to be decided; and it certainly never assumed a cap with the intention of distributing pressure instead of concentrating it. A reversion to a flat head would have been the most effective way of doing that. Nevertheless, the cap does distribute pressure incidentally, and it is not impossible that, in view of its small size, it would not give adequate reinforcement, except at a much higher velocity, if it did not. The cap as a reducer of stress intensity assists plate and shell alike, so the shell derives no differential benefit from it in that capac-

ity; but it gives to the shell alone additional strength to bear compression stress, and that is where its advantage to the latter comes in.

If, in addition to laterally reinforcing the projectile's point the cap itself were to disintegrate the hard face of the plate before the shell arrived, another reason would be furnished to explain the reduced liability to rupture of a capped shell. The writer, however, is inclined to think that a velocity high enough to save the soft cap from complete deformation would, *a fortiori*, be high enough to save the shell's point from pulverization. It would, in fact, be not less than the third critical velocity (which, it is thought, must always greatly exceed bare perforating velocity), and then the cap would be unnecessary.

That the kinetic energy possessed by the cap when attached to the shell is not an essential is proved by the fact that a 2-inch wrought-iron plate placed in front of a hard face gives perfect protection from pulverization on impact. This can only act as a lateral reinforcer, for of kinetic energy it has none. The writer's own punching experiments also prove clearly that high velocity, *per se*, is not an essential. The cap on a punch is quite efficient when velocity of impact does not exceed a few feet per second, provided its diameter is not too scanty. The wrought-iron plate quoted above is analogous to a cap with a diameter of several feet, and so should be independent of velocity as well as (as proved) of kinetic energy. Caps of usual form, however, have far too small a diameter to give adequate reinforcement by their resistance to slow stretching, and the writer believes it is for this reason alone that they fail to save the point of the shell until a certain velocity has been reached. If considerably more diameter were allowed to caps their inefficiency at low-striking velocities would probably diminish and possibly disappear.

But the fact that the success of the cap does not depend on it is no justification for disregarding its kinetic energy. If this energy were very great, owing to extremely high veloc-

ity, there can be no doubt the flattening of the cap would not be complete before the occurrence of failure in the plate's face; in such a case the projectile on its arrival would find some of its work done for it. There are reasons, however, for believing that such velocity is not attained in usual practice. Chief among them is the fact that when an uncapped projectile is pulverized on impact—which, it is thought, implies higher stress intensity than is involved in the flattening of any cap—a portion of the original face of the plate some inches in diameter is commonly found to have been driven back intact, showing that it has been able to bear all the stress intensity of the earlier stages of impact, and has only yielded by its peripheral attachment to the plate giving way under the large amount of total pressure that is of later occurrence.*

The writer, therefore, prefers to hold for the present the view that the main function of the cap is lateral reinforcement of the weak point of the shell; that incidentally it reduces stress intensity for both plate and projectile; and that, at current striking velocities, no serious preparatory work is done by it on the plate before the arrival of the shell itself.

Experiments might with great advantage be made to test against each other the two extreme forms of cap, namely, one with a flat head of the greatest admissible diameter projecting very slightly beyond the point of the shell, and the other with an ogival point, like that of the projectile, and projecting 2 inches or 3 inches in advance of it. If the former proved as good as the latter, it would be worth while to try the effect of making it of a stronger material than mild steel; for, although the long-pointed cap must be highly ductile, it does not follow that the flattened one need not be more than moderately so.

All the foregoing remarks have reference to impacts normal to the face of the plate. The subject of oblique impact,

* The diagram in Fig. 14, where striking velocity is about a practical maximum for the present day, seems to suggest a maximum intensity of stress on the plate of no more than 70 or 80 tons per square inch before the arrival of the shell itself.

though very important, is so intricate that considerations of space preclude more than a brief mention of it in these notes.

There are two kinds of oblique impact, of which only one —that of the inclination of the trajectory to the normal to the plate—has hitherto been generally recognized. In this kind the apex of the projectile is practically, if not absolutely, in the line drawn from its center of gravity to the point of impact, and the blow of the shell itself is fairly delivered through its point. In the other kind, which involves still more serious risk of fracture to the shell, its own axis is inclined to its trajectory, while the latter may or may not be inclined to the normal to the plate.

Consider a 12-inch capped shell, loaded and fused, fired at vertical armor at 8,000 yards. Suppose also that on leaving the muzzle it has its axis pointing upwards 4 degrees, its velocity of translation being 2,700 f.s., and of axial rotation 5,400 revolutions per minute. The gyrostatic action due to the axial rotation, though considerably reduced by air friction in flight, may be expected to remain powerful to the last; for, even if the speed of rotation were to lose as much in proportion as that of translation, which is far from being the case, the former would be 3,300 revolutions per minute when the latter had come down to its remaining value for the given range of, say, about 1,500 f.s. The center of gravity of the shell being no more than 0.87 inch in advance of the center of figure, the "righting moment" of the air resistance has only a leverage varying from zero to a maximum of 0.151 inch, and so must be very small (leaving out of account the additional complication of the precessional movement started when the position of a gyrostat's axis is forcibly altered); but, as its influence is at least in the desired direction, we may rely upon the air resistance not increasing the unfavorable angle, and so the worst case will be made out by ignoring it altogether, and assuming that the gyrostatic action is unopposed and retains the shell's axis pointing upwards at 4 degrees when impact takes place and the trajectory is pointing downwards at 6 degrees. Fig. 16 illustrates this con-

dition, and it will be realized that the angle (10 degrees) between axis and trajectory is much more unfavorable for the projectile than a considerably larger angle would be between trajectory and normal to the plate. A "couple" with an arm about 4 inches long is formed by the momentum of the shell acting along its trajectory and through its center of gravity, and the reaction of the plate acting in an opposite parallel direction through the point of impact. This couple must have a powerful cross-breaking effect on the shell.

If the roll of the attacked ship brings its side armor normal to the trajectory at the moment of impact, it increases the obliquity between the axis of shell and the normal from 4 degrees to 10 degrees; and if the roll is in the other direction, and brings the shell's axis into the normal, it increases the obliquity of the trajectory from 6 degrees to 10 degrees. All this is supposing there is no obliquity whatever in a horizontal plane. On the whole, it would appear that truly normal impact at long range is not simply unlikely, but may be actually impossible; whence it is a reasonable inference that the defensive power of armor under the probable conditions of a naval action will be greater than suggested by results obtained with the same striking velocity at short range on the proving grounds.

A KEYLESS LOOSE COUPLING.

By Captain A. B. Willits, Member.

About a year ago the writer devised a novel loose coupling for use in small steamers, launches, etc., where the withdrawal of the tail shaft having a solid flange coupling usually necessitated the removal of the engine as a preliminary. This device has not been patented, although no patent coupling in the records of the Patent Office touched upon the principle involved. Hence its use is free to any one desiring such a convenient arrangement, the patenting of the invention not being considered worth while or necessary. In the wild state of the "market" just now couplings do not seem to be very conspicuously "bulled," and huge fortunes are not usually harassing the inventor of articles, however useful, which never wear out.

The peculiarity of this coupling lies in its being keyless. Its principle is that of the eccentric whose yoke, being prevented, by bolting, from reciprocatory movement, rotates the eccentric absolutely with itself.

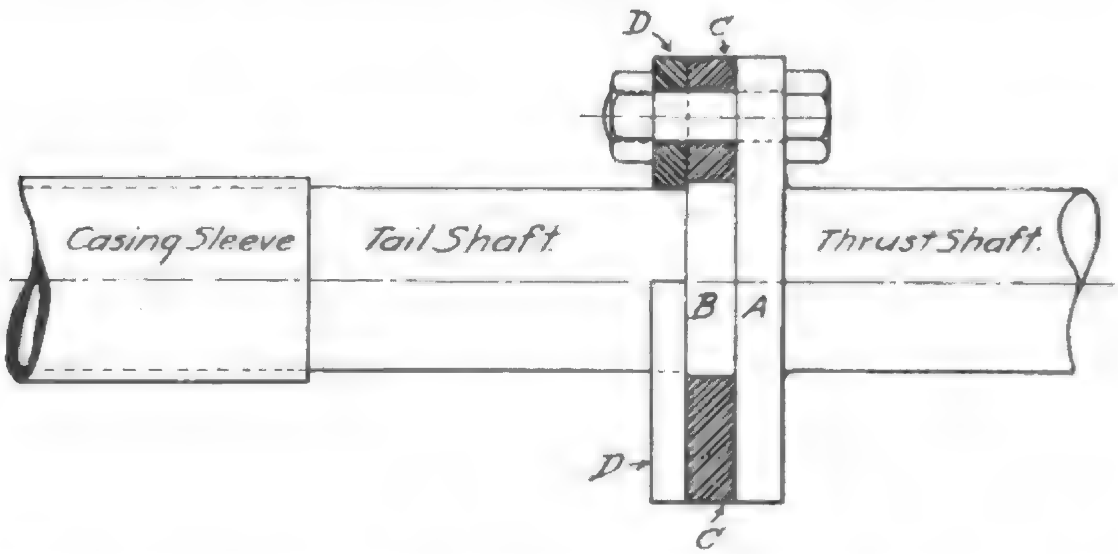
The figure is readily comprehended, and but few words of description are required.

A portion, B, of the forward end of the tail shaft is turned to a larger diameter than the shaft (not to exceed the diameter of the tail-shaft casing or journal at stem bearing) and out of center as much as will give all the eccentricity possible with such increased diameter without quite fairing it, at any part of the circumference, with the tail-shaft surface. This to give at least a trifling lip all around for the purpose hereafter noted.

The loose coupling, C, is turned to an outside diameter exactly equal to that of the solid coupling, A, of crank shaft,

and is then bored eccentrically to the exact amount, and with exactly the same diameter as the eccentric portion B.

Center lines are permanently scribed on the forward end of tail shaft and on the loose-coupling disc before eccentric turning and boring is done, the new centers being in these lines in both cases. This permits the ready adjustment of the coupling disc C on the eccentric B without disturbing the alignment of tail and thrust shaft when bolted up, and with the disc C snugly and properly in place the coupling-bolt holes are drilled or bored and reamed out true and fitted with



body-bound bolts. Two half discs, D, are fitted snugly to the tail-shaft diameter, facing against the lips of the eccentric B and the loose coupling, and holding the shaft from pulling out when backing. These also prevent the tail shaft from turning on its axis around the axis of the eccentric, and these half discs, therefore, must be fitted up and bolted as accurately as are the couplings. To draw out the tail shaft all that is necessary is to remove the coupling bolts from the half discs.

As to how useful this device would be found on large shafting the deponent sayeth naught, but as a neat little device for light work it is commendably cheap and simple.

MODERN TORPEDO BOATS AND DESTROYERS.*

By J. E. Thornycroft.

Since the introduction of the torpedo-boat destroyer, rather more than twelve years ago, such changes have taken place in the construction, and the torpedo boat itself has been enlarged to such an extent, that a review of the developments may be of some value.

Considering the vessels of the British Navy, it will be found that the largest torpedo boats were vessels of about 130 tons displacement and 2,000 indicated horsepower, developing a speed of 23 knots. They were, with one exception, single-screw boats, and were, except in a few cases, fitted with locomotive boilers. The majority of the boats were considerably smaller, and only had a speed of about 20 knots. The only watertight compartments were formed by the bulkheads—watertight flats in the compartments at the end of the vessels not having been at that time adopted. The most powerfully-armed were fitted with one bow and two deck tubes for 18-inch torpedoes and three 3-pounder guns.

At the same time the French and German Navies possessed a large number of torpedo boats of about the same size and power, but differing greatly in design from the British boats. The French design of boat came primarily from the yard of Normand, and the German from that of Schichau. In addition to their torpedo boats, the German Navy possessed a number of much larger and more powerful boats, which were called "Division" boats. These were employed with the torpedo boats, and carried the commanding officers of each division. Although they were vessels of considerable tonnage,

* Paper read before the Institution of Naval Architects, April 8, 1908.

being over 300 tons, they did not develop a much greater speed than the torpedo boats.

The history of the inception of the torpedo-boat destroyer in the British Navy is so well known as to require only a passing reference. The efficiency of machinery which had been fitted to the torpedo-gunboat class being insufficient to enable them to develop a higher speed than the torpedo boats, the British Admiralty decided that vessels of the torpedo-boat type should be built of sufficient power and dimensions to insure their being able to always overtake and destroy torpedo boats with the guns they carried.

The first vessels of this new class, which were called torpedo-boat destroyers, were built by Messrs. Yarrow (*Havoc* and *Hornet*) and Messrs. Thornycroft (*Daring* and *Decoy*). Their trial displacement was about 240 tons, and the power developed was over 4,000 indicated horsepower, which gave a speed of 27 knots. They had a high free board, were excellent sea boats, and were able to maintain their speed in rough weather. Although in dimensions they were somewhat smaller than the German division boats, their greatly increased speed gave them a much higher fighting value, and they were considered such a success that forty more were put in hand during the next two years. It was the introduction of water-tube boilers in these vessels which primarily enabled this high speed to be obtained, and their working was so successful that these boilers were at once adopted by every builder of this class of vessel.

During the next few years the experience gained with them when keeping at sea for considerable periods made it desirable to increase the size and power, and six years after the first boats were built the new vessels that were being put in hand had been increased in size by about 100 tons, and the power from rather over 4,000 to 6,000 indicated horsepower. Their strength and safety had been very much improved by the introduction of watertight flats in the end compartments. The bow torpedo tube had been dispensed with, and their speed had been increased to 30 knots by the employment of high-

tensile steel in their hulls, and improvements in their machinery. The earlier vessels were constructed of steel of the character usually employed in ship construction, but the high-grade steel employed in these later boats had a tensile strength of between 37 and 43 tons, and was so tough as to show an elongation of 15 per cent. on an 8-inch test piece. The employment of this steel was a very important departure, as it enabled 15 per cent. of the weight to be saved in the structure of the hull. The stresses in the hull were about 9 tons in tension and 7½ tons in compression. Perfectly satisfactory results were obtained, and trouble was only experienced in some isolated cases where local stiffening or compensation had been insufficiently considered. During maneuvers, and in making long passages, some instances occurred in which it was thought that greater strength might be advantageous, but the damage sustained was not greater than might have been expected to happen to any vessels under similar circumstances. The fact that all the Japanese destroyers built by British firms made the voyage to the Far East, were at once put into service without any repairs, and went through the war without developing any structural defects, proves that this class of vessel was of ample strength.

After the British Navy had taken the lead, we find that the more important foreign navies quickly followed its example. The new division boats in Germany were built with water-tube boilers, and at once became available as torpedo-boat destroyers. There is, however, considerable difference between these vessels and the British, the German vessels having a very much lower freeboard and drawing more water, besides being fitted with a submerged bow tube.

Mr. Ziese says that the attention of his firm (Messrs. Schichau) is specially directed to designing their vessels to be as low as possible in the water to reduce them to the minimum target. It will be seen from the comparative designs that the typical German vessel (Fig. 9), is much less prominent in this respect than the later British vessels (Figs. 7 and 8). The German vessel is a good deal finer forward,

and the greatest beam is placed further aft; the stern is deep and narrow, quite unlike the broad, flat British sterns. The bridge is kept back as far as possible, being quite close to the forward funnel, one or more deck tubes being placed in front of it and behind the low turtle back. This is, no doubt, a good position for them from a control point of view, but it is thought doubtful if they can be so efficiently worked in bad weather as the British vessels, with their greater freeboard and the torpedo tubes aft.

The destroyers built in France (Figs. 1 to 6) have also a very low freeboard compared with the British boats, and possess quite a special construction of hull. The late M. Normand, and some of the leading French naval architects, were of opinion that much greater strength and security in bad weather are obtained by constructing a vessel with a turtle-back form from one end to the other. This form originated with the Normand torpedo-boats, and was developed to such a degree of exaggeration in the French destroyers that a platform or hurricane deck had to be provided to enable the crew to work the guns and get from one end of the vessel to the other. The hatchway coamings, skylights, etc., are all brought up to this platform, so that the seas can wash over the deck of the vessel—the crew standing above the water. No doubt a considerable amount of weight may be saved by this construction, but it is doubtful if the vessel can be so efficiently worked in bad weather as one with a much greater freeboard. It must not be forgotten that a type of boat may be suited to one class of sea and coast although not successful in another, and the French type may be all that is required for the Channel, but would not do so well for the North Sea or the Atlantic. M. Normand has informed the author, however, that in the latest destroyers of large dimensions which he is building he has abandoned this special construction, and has adopted much more the British type, as will be seen from Figs. 1 and 2, which he has kindly supplied, showing one of his latest vessels. It is understood that this change is not in any way because the construction is unsatisfactory, but simply

Fig. 1.
FRENCH DESTROYER. "CHASSEUR" CLASS.

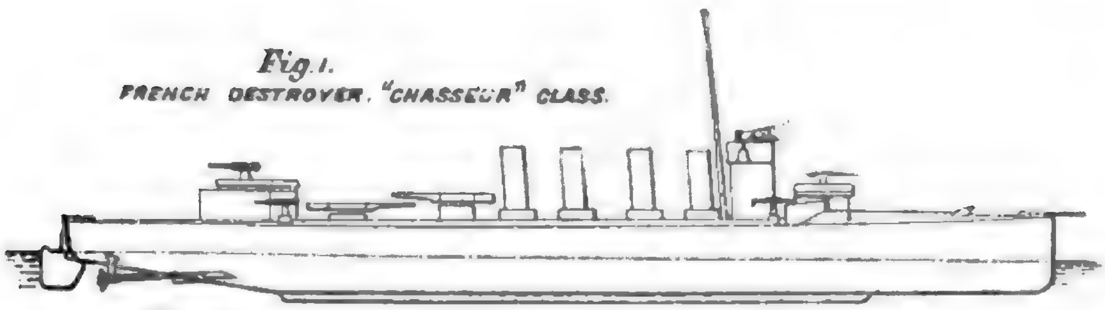


Fig. 2.

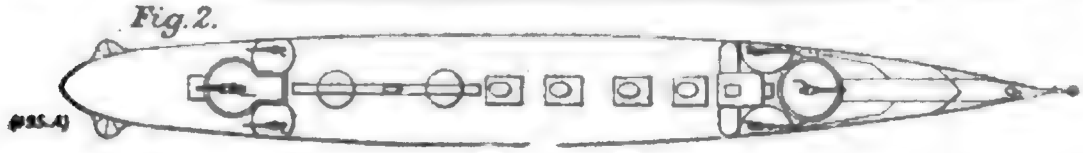


Fig. 3.
FRENCH DESTROYER "BRANLEBAS" CLASS.

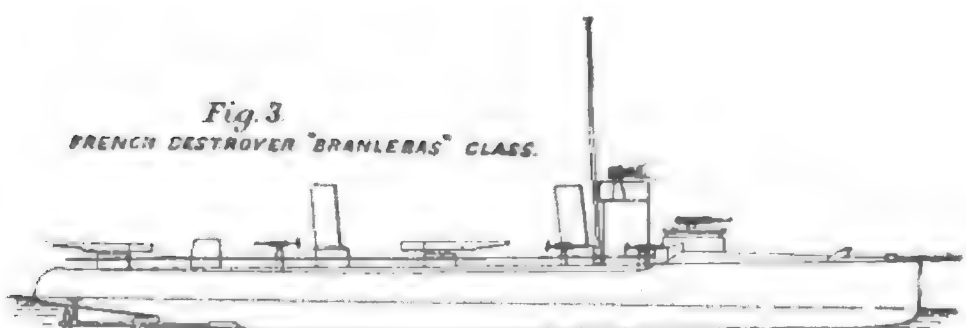


Fig. 4.

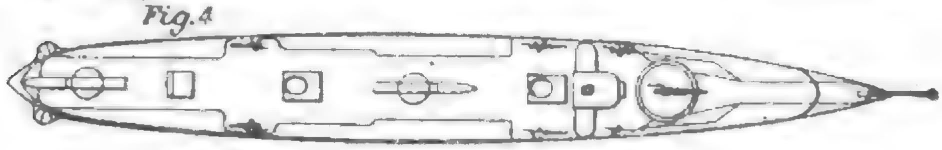


Fig. 5. FRENCH DESTROYER "YATAGAN" CLASS.

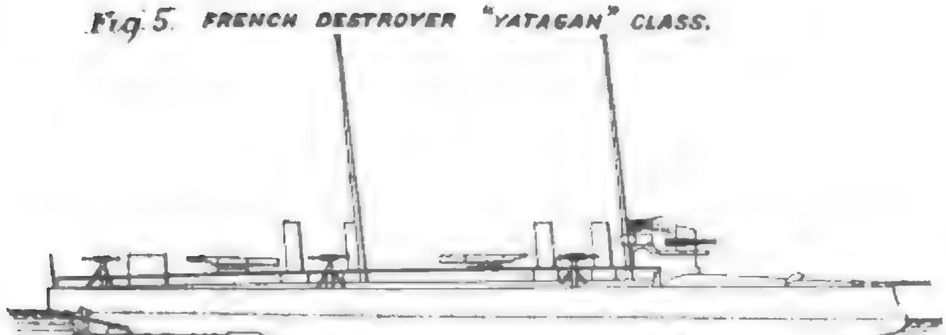
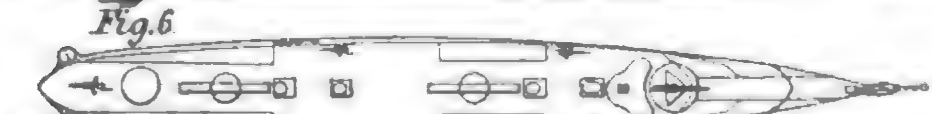


Fig. 6.



that it is less suited to larger vessels, and is more costly. In support of the advantage of what may be described as the British type of vessel, it is interesting to note that besides the Japanese, most navies that have built destroyers have adopted British designs. The British naval authorities have considered the efficiency of destroyers in bad weather to be of such importance that in 1901 it was decided that, in the new vessels, speed should be reduced to the extent of 4½ knots to obtain better sea-keeping qualities and greater strength of hull, and more comfort for officers and men. These vessels were known as the "River" class (Figs. 7 and 8), and while

Fig. 7. BRITISH DESTROYER "RIVER" CLASS.

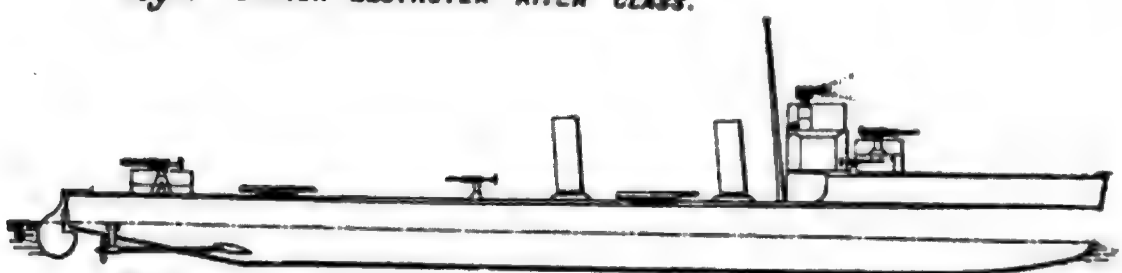
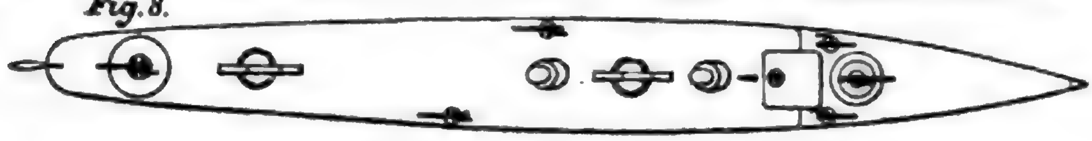


Fig. 8.



opinions differ as to their fighting value compared with that of the earlier 30-knot boats, it has been conceded that the reduction of speed was too great. There has been no falling off in the demand for high speed in vessels built by foreign navies, and the latest destroyers built for the British Navy have been designed for a speed of not less than 33 knots.

The River class destroyers have a displacement of 525 tons, and develop about 8,000 indicated horsepower, which gives a speed of 25¼ knots. Not only are they of greater freeboard and beam, but have a high forecastle, the deck of which is about 14 feet above the water. This makes them very comfortable and roomy boats, but, of course, much more conspicuous.

Vessels with hulls of this type are now being built for a foreign navy, where they will be required to work in very

open water, and they have also been proposed for the Australian Commonwealth, where similar conditions prevail. The officers who are responsible for this decision have also made the proposal to put the officers' quarters in the fore part of the vessel. The suggestion has often been considered before, but could not be carried out satisfactorily without the extra room provided by the double forecastle.

Reference has been made to the kind of stern adopted in the majority of the German vessels being different to what has been described as the "British type." The form of stern

Fig. 9 STERNS OF "THORNYCROFT" DESTROYERS WITH DOUBLE & SINGLE RUDDERS.

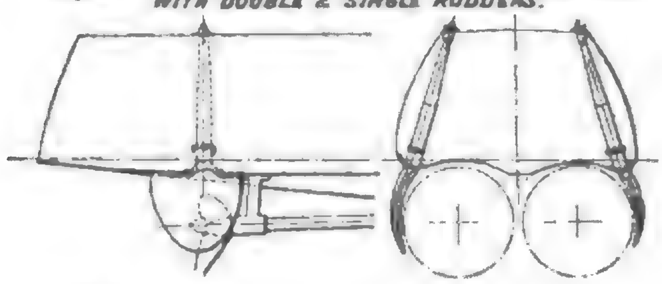
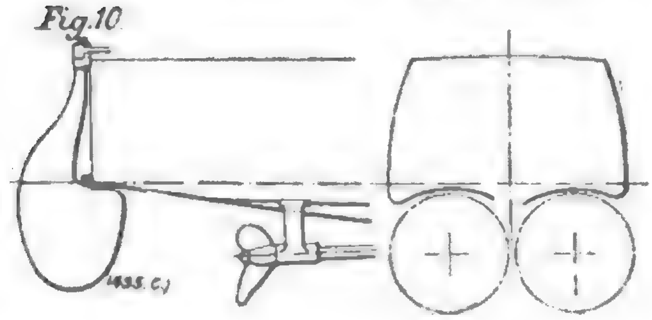


Fig. 10



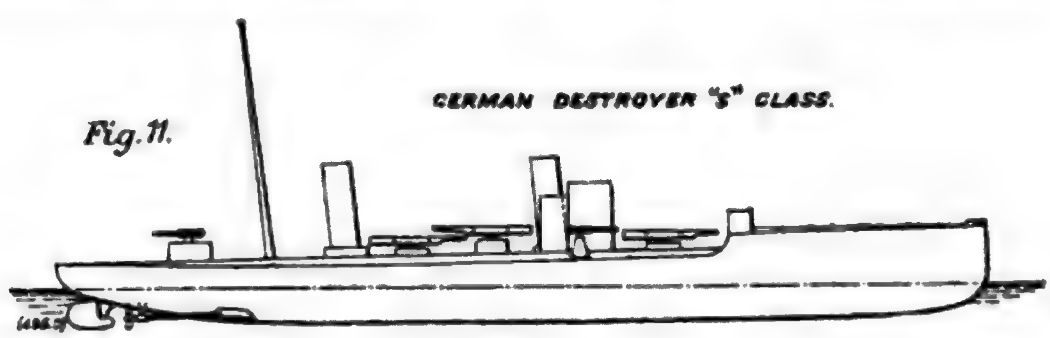
necessarily largely determines the type of rudder that can be fitted. As in other matters, there appears to be considerable difference in opinion as to the amount of steering control which is necessary. The diagram, Fig. 9, shows a broad stern and double rudders as fitted to the first of the destroyer class, *Daring*, &c., which was copied from the earlier Thornycroft torpedo boats. The arrangement of two rudders, one on each side of the screws, probably gives the best possible steering qualities, both ahead and astern, but has the disadvantage of the complication of two rudders.

It will be seen that the German type of rudder, as fitted by

Messrs. Schichau, is very much more of the ordinary cruiser type of balance rudder (Fig. 11). In some of the fastest of the French boats the rudder has been fitted forward of the screws, but in the later vessels it is arranged like the British boats, with the rudder spindle outside the stern of the vessel. Opinions differ very much as to the advisability of protecting the rudder, which may be done by placing it under the stern or by means of an overhanging counter; but if either of these methods is adopted, it is much more troublesome to unship the rudder than when it is placed clear of the vessel.

The difficulty of steering astern with a single-screw boat is thoroughly understood, and on this account alone there is a strong argument in favor of twin screws for all torpedo craft. The speed at which torpedo craft should be required to be controlled astern is one which must be fixed by naval officers.

Fig. 11.



While the very best stopping power will be recognized as of the first importance, it is thought questionable if the steering-gear should be required to control the vessel at more than 20 knots astern.

The new 33-knot type of destroyer, of which five have been built and seven are in course of construction or about to be put in hand, is of between 800 and 1,000 tons displacement, and is nominally of about 15,000 indicated horsepower. Experience gained with the experimental vessels *Albatross* and *Express*, intended for a speed of 32 knots, seemed to show that with reciprocating engines it would be very difficult to develop higher speed, and therefore in these new vessels, where a speed of 33 knots was demanded, it was decided, in view of the favorable results that had been obtained with Par-

sons turbines in the several torpedo-boat destroyers in which they had been tried, to adopt them for the new vessels. It is now generally known that, in conjunction with oil-fired boilers, the turbine engines have given results which could not have been obtained without their adoption. The *Tartar*, the fastest of the class, has maintained a speed of 35.36 knots on a continuous run of six hours, or practically 10 knots more than the River class could maintain on a four, instead of a six-hours' trial. While giving every credit due to the turbines and oil fuel for the part they have played in enabling this result to be obtained, it will be agreed that the greatest credit is due to Mr. S. W. Barnaby and the other officers of the firm who have been responsible for the design and building of the vessel. The increase in size over the earlier types which has been found necessary to enable this speed to be obtained with the required radius of action, has been very considerable, the length in the case of the *Tartar* being 272 feet, as against 225 feet in the River class, and the displacement nearly 900 tons, instead of 600 tons. It is worth noting that the strength and proportions of all the individual parts have been kept up to the standard of the River class, and the stresses in the structure of hull do not exceed 8 tons in tension and 6½ tons in compression, these being the limits which have been laid down by the Admiralty as necessary for this type of vessel.

Apart from the coal capacity of a destroyer, the duration of time for which full speed can be maintained depends on the length of time it is possible to run without cleaning the fires, which at full speed, with average coal, is not more than three or four hours. With liquid fuel, stoking is reduced to a minimum, and full speed can be maintained as long as the fuel lasts. The importance of the most skillful attention to reciprocating engines is well known. With turbines, both the number of men and the closeness of attention are very greatly reduced, and it is considered that the difference which has been made by the use of turbines and liquid fuel in these vessels has had as great an effect as the introduction of the

water-tube boilers in the first destroyers. The extent to which destroyers of this power will be adopted by foreign navies is uncertain in view of their very great expense, and in their programs it will be found that vessels of what may be described as an improved British 30-knot class are being adopted.

While the destroyers have been shown to have increased in size and power very greatly from the original type, the torpedo boat has developed almost to an equal extent. In each succeeding order for the British Navy torpedo boats have been made rather larger than their predecessors, until the last reciprocating-engine boats ordered in 1903, which were of 200 tons displacement and 2,900 indicated horsepower, gave a speed of 25½ knots; they carried three 18-inch torpedo tubes and three 6-pounder guns. The latest types of torpedo boats were ordered in 1905, and were at first called "coastal destroyers." They carried the same torpedo armament, were of slightly greater dimensions, but were fitted with turbines and oil fuel, and as far as power and speed are concerned they are practically the same as the first 27-knot destroyers. The adoption of oil fuel, however, has given them a much greater radius of action at full speed.

While the turbines have given excellent results in these vessels, it is a question if equally good results would not have been obtained with twin-screw reciprocating engines and oil fuel, as, while the merits of turbines for larger vessels are admitted on all hands, there is considerable doubt, when powers of less than 3,000 or 4,000 indicated horsepower are required, if the greater simplicity of reciprocating engines is not to be preferred. The necessity of adding a cruising turbine and, owing to the high speed of revolution, of adopting at least three shafts, makes it extremely difficult to arrange the engine room satisfactorily in such small vessels. No doubt with experience it will be found possible to simplify to some extent the arrangement of pipes and auxiliary engines, but in their present form these adjuncts amount to so much that the fitting of the machinery on board becomes an extremely

costly matter, and when it is necessary to open up, an enormous amount of work is entailed. It is thought that it will always be found necessary to put these vessels in dockyard hands if any adjustments have to be made to the machinery, as it will be quite impossible for the crew themselves to deal with adjustments without greater facilities than can be provided on the vessels.

It is believed that it will soon be recognized that the procedure which has always obtained with regard to opening up the machinery after the contractors' trials, and the periodical opening up for inspection, should, with turbine machinery, be discontinued, as not only are so much labor and time wasted, but considerable risk occurs every time the engines are opened up. When once they have been properly adjusted, there is not the same reason for examining the rotors, etc., that exists for looking at the pistons and slide valves of reciprocating engines.

The arrangement of turbines that Messrs. Parsons have thought best for smaller powers, from considerations of simplicity and lightness, is that of three shafts, viz: the high-pressure turbine on one wing shaft, the intermediate-pressure turbine on another and the low-pressure turbine, of more than one-third power, on the center shaft. As the reversing turbine is necessarily a part of the low-pressure turbine, only one shaft is available for astern going, so that from the control and steering point of view the vessel is practically a single-screw one. Some of the earlier turbine vessels did not have very good astern power, but in the later torpedo boats, and particularly in the 33-knot destroyers, the astern-going power has been enormous, the later vessels being capable of making upwards of 25 knots astern.

In the Italian Navy there are excellent examples of torpedo boats of 26 knots speed, fitted with twin-screw reciprocating engines, a considerable number having been built by the firms of Messrs. Pattison and Messrs. Odero, from designs supplied by the author's firm. They have three 18-inch deck tubes and three 3-pounder guns. Although they are

under 200 tons displacement, they are able to withstand heavy weather. For some years all the torpedo boats for the Italian Navy have had their coal bunkers arranged so that they may be used for oil tanks when required. Coal protection to the machinery, however, has been considered of such importance that liquid fuel has so far only been adopted to a limited extent.

The three deck tubes are arranged in the same way as has been adopted in the German Navy, viz: one aft and two forward in front of the bridge and behind the turtleback. It will be noticed that the vessel has a straight keel of sufficient length to enable it to be docked without supporting the overhanging ends. This is a feature which is found most convenient, and has been generally adopted in modern vessels in place of the "cambered" keel fitted to the early torpedo boats. The screws project very little below the line of keel, which is also a good feature where there is any likelihood of the vessels taking the ground.

The possibility of vessels frequently taking the ground in certain navies has been considered of such importance that torpedo boats have been fitted with a false keel in order that the propellers may be protected. The heelpiece, which it was at one time thought desirable to fit under the propeller itself, being found worse than useless, has now been entirely abandoned. This false keel must, however, detract materially from the speed.

The particular coast and condition of service must, of course, be taken into consideration in the case of torpedo boats as well as destroyers, and it is possible that small vessels may be successful in some cases; but it is thought doubtful if, as a rule, good results will be obtained with vessels of much less than 180 tons. It is true that the latest British torpedo boats which are building are nearly 100 tons greater displacement, but they bear about the same relation to torpedo boats of other navies that the 33-knot destroyers do to destroyers of our own and other navies. While questions of cost may not be of the first importance in the British

Navy, there are a number of countries at the present time contemplating the building of torpedo-boat craft where the amount to be expended on individual vessels will be one of the first considerations.

When considering the advantages of employing oil fuel for this class of vessel, its comparative high cost and the difficulty in obtaining it must not be overlooked. The features that strike those who are actually working the vessels most forcibly are the absence of dirt and cinders, and the saving in stokehold staff, the moving of fuel and stoking being effected by steam pumps and pipes instead of stokers and trimmers. With coal-fired torpedo boats it may be taken that the stokehold staff will be quite three times as great as with oil-burning boats; and while with coal firing at full speed it is usually difficult to maintain sufficient steam, in practice it is found that oil-fired boilers are blowing off, or on the verge of doing so; and when the vessel is eased up the boilers are under such perfect control that the safety valves do not lift. The necessity of easing down gradually to avoid blowing off with coal-fired boilers is, of course, thoroughly appreciated.

The evaporative value of oil may be taken as one and a third times that of coal; and while 43 cubic feet of bunker space are required to stow a ton of coal, 38 cubic feet of space are required to stow a ton of oil, so that the equivalent amount of oil fuel can be stowed in 70 per cent. of the space required for coal.

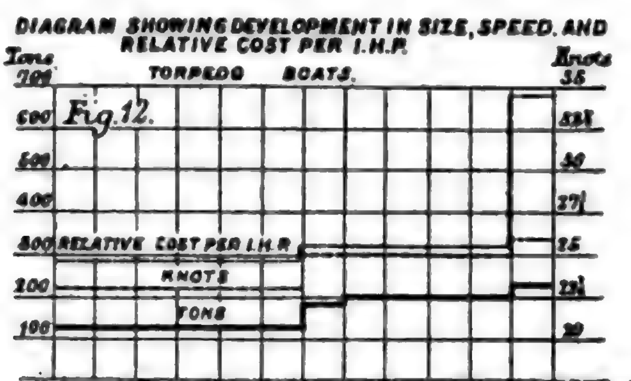
The consideration of cost is not of the first importance in fuel for warships, but it is worthy of note that the most recent oil-tank steamers have not been fitted to use oil fuel on account of the cost, although some years ago, when Sir Fortescue Flannery read a paper on the subject at the Institution, it was expected that many vessels would soon be so fitted.

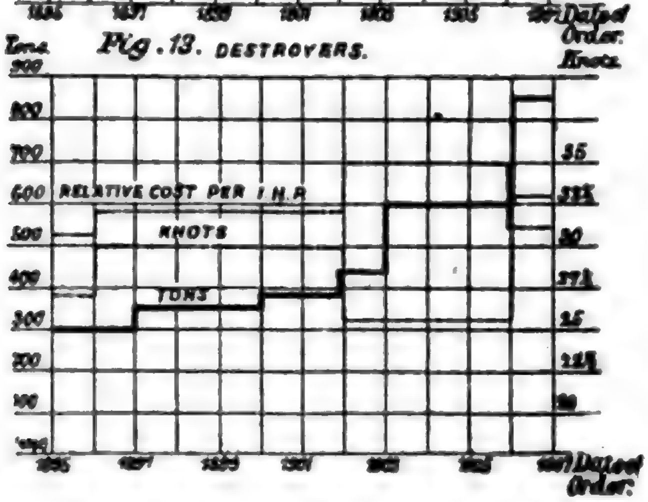
It is interesting to compare the radius of action of the coal and oil-fired torpedo boats and destroyers; but it is difficult to draw any definite conclusions in view of the coal-burning boats being generally fitted with reciprocating engines and the oil-fired boats with turbines.

It is not proposed to go into the considerations of the relative economies of reciprocating and turbine machinery, as it is recognized that while the turbines have a very high efficiency at full power, at cruising speeds, even when using the cruising turbine, their efficiency is much less than that of reciprocating engines.

In the case of the torpedo boats which have been delivered to China and Japan, it has been necessary to consider their capacity to carry coal for the voyage from Aden to Colombo, and without very special arrangements it is doubtful if turbine vessels could make the voyage; while Messrs. Schichau have informed the author that the vessels which they have built for the Chinese Government actually made the voyage from Port Said to Colombo without taking any coal or water at Aden, a total distance of about 3,700 miles.

It will be noted from the diagrams, Figs. 12 and 13, showing the increase in size of torpedo vessels, that in the case of the torpedo boats the tonnage, speed and price per horsepower have varied in approximately the same proportion,





but as soon as the change to turbines takes place the price per horsepower goes up very considerably. In the case of destroyers, the diagram shows that the price per horsepower also varies approximately in proportion to the increased size of boats until the introduction of the turbines in the 33-knot destroyers, when, owing to the very great power developed, the price per horsepower actually falls instead of increases.

It is admitted that to insure freedom from breakdowns, and general efficiency in service with such small vessels, every possible complication must be avoided in the machinery and mechanical devices; but with torpedo boats, like all other ships, every new class seems to require something added to increase the complication. It is thought that the time has arrived when every effort should be made, particularly where turbine machinery is employed, to reduce the number of auxiliary engines. This suggestion will be better appreciated when it is known that in the latest turbine destroyers there are twenty-one independent steam pumps, besides fans, electric light, and other engines.

An effort has been made by Messrs. Yarrow to attain this end in the destroyers building for the Brazilian Government, by fitting two very large boilers instead of four. The resulting simplification and economy in construction are, of course, great, besides a considerable saving in weight; but the advisability of using boilers in units of upwards of 4,000 indicated horsepower is thought to be open to question.

The policy of some naval authorities to duplicate everything, from the main feed pumps to the syrens, is thought to be a mistaken one. The reserve pumps, or whatever piece of mechanism it may be, that are in duplicate ought not to be required to be brought into operation, and in ordinary commercial engineering do not usually exist. In a battleship, which will go on fighting after receiving a great deal of punishment, the conditions may be different; but the torpedo boat or destroyer either escapes or is damaged to such an extent that no duplication will save it.

It is not within the province of the author to express an

opinion on the relative importance of different types of war vessels; but it is hoped that the large number of destroyers and torpedo boats which are building, or contemplated, by the different Powers at the present time will be considered a sufficient justification for this paper.

NOTES.

THE PRICE OF SPEED IN WARSHIPS.

At the present time, when the financial provisions for the Navy are prominently before us, one is led to reflect upon the continual growth in the size and cost of war vessels, and to wonder where the increase is going to end. The cost of the old *Dreadnought* in 1875 was about £55 per ton of displacement, the cost of the 1907 battleship of that name just over £100 per ton of displacement, and while the cost per ton has thus nearly doubled, on account of the increase of size, the total cost of the ship has trebled. The price of the raw materials which go to make the finished ship has, we suppose, on the whole, not materially altered in this period, and the greatly increased cost per ton is thus mainly due to the increase of the amount of labor which is put into the material. The successive improvements which have taken place in machinery have been in the direction of obtaining a greater output for a given weight, and this has inevitably meant more costly methods of production. It is not necessary to dwell on this point, instances of the truth of which will immediately occur to anyone who thinks for a moment on any one of the numerous mechanical appliances which go to make up a modern warship; but, as a specific instance, we will only ask the reader to reflect upon the amount of labor which is put into a water-tube boiler weighing, say, 10 tons, compared with the amount of labor required in a cylindrical boiler of the same weight. The increase in cost, both total and per ton, may all be attributed to increase of speed in one form or another. The speed of the vessels has been steadily increasing, necessitating higher-powered machinery, and in order to obtain the increased speed without unduly increasing the

power, length of ship and, therefore, displacement must also be increased. Speed of firing the guns has increased, leading to more elaborate and costly gun mountings, and a whole host of subsidiary appliances for handling the ammunition with a facility corresponding to the rapidity of fire; and, lastly, the increase of muzzle velocity of the projectiles has necessitated improvement in the armor so that the same weight of it shall have correspondingly greater resisting power.

The study of this process of evolution which is still going on, the various factors in it, and the way in which they react upon each other, is very fascinating, but on the present occasion we desire to limit attention to the question as affecting one class of war vessels—torpedo craft. The problem in this class does not involve the same complications as in the cruiser or battleship, since armor does not enter into the question at all, while the weight of armament is a small proportion of the displacement, and is governed mainly by considerations of stability and space. The evolution of this type of vessel has, therefore, been almost entirely in the direction of increase of speed, and though some of the advance has been due to lighter hulls, as a result of the employment of high-tensile steel, the main factor has been the successive improvement in the propelling machinery. The *Lightning*, the earliest vessel of the type, in 1877 attained the "unprecedented" speed of 17 knots, and was followed by a number of second-class torpedo boats of small displacement and about the same speed, some of which were intended to be carried on board battleships and cruisers. They had special arrangements for filling their boilers with hot water from the boilers of the parent ship through a hose connection on the vessel's side, with the idea that the boat could be lowered into the water and steam raised in a very short time and the boat despatched to deliver an attack on an enemy not many miles distant.

The possibilities of circumstances arising in actual warfare for such a use of these boats without hampering the movements of the parent ship was seen to be remote. The additional "top hamper" which the carrying of them entailed

was objectionable; they were extremely frail and liable to damage in the operations of hoisting and lowering; they were not very seaworthy and, of course, could not be lowered except in smooth water, and they consequently soon ceased to be carried. Though torpedo-dropping gear is still fitted in the larger steamboats carried on board big ships, it has never been seriously proposed to return to a small torpedo boat carried on board. These boats were followed in the eighties by a number of first-class torpedo boats which, as they were capable of keeping the sea in moderate weather, may be considered as the real starting point in the line of sea-going torpedo craft. Their trial speeds were about 20 knots, and their indicated horsepower varied from 700 to 1,500. The latter of these have in the last year or two been reboilered with water-tube boilers in place of the locomotive boilers with which they were originally fitted. Following these, in the early nineties, came the larger boats *Nos. 91*, *92*, &c., the first to be fitted with water-tube boilers. They displaced about 120 tons, the indicated horsepower was about 2,000, and the speed 23 knots. The possibilities of the water-tube boiler had for some time been under observation, and the great advantage which the small-tube or "Express" type gave in point of steam-giving capacity on a small weight made possible a large advance in size and speed, and the torpedo-boat destroyer was evolved. Thenceforward torpedo craft became divided into two distinct classes—the torpedo boat proper and the torpedo-boat destroyer—and we need only, in the course of the present article, follow the development of the latter. The first torpedo-boat destroyers had a speed of 27 knots on trial with about 4,500 indicated horsepower, and they displaced about 250 tons. As might be expected in vessels so large a step in advance of their predecessors, they did not live up to their trial performance on service. Following these, in the closing years of the last century, came the 30-knot boats, in which the displacement was further increased to about 360 tons and the indicated horsepower to 6,000. Up to this time it was the custom to specify that the trials should be run car-

rying a certain load on board, and this load gave to the boat a displacement less than it would have on service, and, as in the case of the previous class, the speed fell off by two to three knots after the boat was commisioned. In the three vessels, *Express*, *Albatross* and *Arab*, tried about the same time, an attempt was made to exceed the previous results by two or three knots, but the results were disappointing. The displacement in these boats was increased to about 450 tons and the indicated horsepower to 7,500 in the case of the *Albatross*, to 9,000 in the case of the *Express*, and it almost appeared that the limit of power had been reached with reciprocating engines of the type required in destroyers. As the result of experience with some of the 30-knot boats at sea it was deemed necessary in the "River" class which followed to increase the scantlings of the hull, and the displacement was increased to about 600 tons. The indicated horsepower was not advanced, remaining at 7,500, consequently the speed was not so ambitious, but a departure was made in running the trials of these boats at their seagoing displacement. They all attained their designed speed of 25½ knots easily, and have maintained it on service, and except in dead smooth water they are, on account of their size, superior in speed to any of their predecessors. In the meantime the turbine was being steadily developed, and the *Viper* had shown that with this form of propulsion speeds were possible which from previous experience seemed out of reach with reciprocating engines. The experiments with oil fuel at the same time showed that by this means steam production could be increased, and it was a logical conclusion to combine the oil-fired boilers with turbine engines, so that the latter could take full advantage of the increased capacity of the former. The result was the "Tribal" class, where the displacement is increased to nearly 900 tons and the horsepower to 15,000. The combination of oil fuel and turbines is still further to be tested in the *Swift*, now nearing completion, where the designed speed is 36 knots, which is estimated will be obtained with 30,000 horsepower, and the displacement is no less that 1,800 tons.

The preceding sketch of the development of the destroyer is necessarily brief, and some details have been omitted, but it serves to show at what price speed has been obtained. Except in the case of the *Amazon* and the *Saracen* of the "Tribal" class, and the *Swift*, which carry 4-inch guns, none of these destroyers carry anything bigger than a 12-pounder, and as regards torpedo armament there is little to choose between any of them. The larger vessels have, of course, better sea-keeping qualities, and higher possible speeds in rough water; but apart from this practically the only advantage gained by the increase in size has been that of speed. From the trial results of the "Tribal" class the *Swift* should reach her 36 knots, providing propeller difficulties do not intervene, and it is not difficult to predict what still further increase in speed would involve. To get 40 knots would mean a vessel of 3,000 tons displacement with about 55,000 horsepower. The cost of the *Swift* is given in the estimates as a quarter of a million; the cost of the 40-knotter would be nearly half a million. It may reasonably be asked, are we getting an adequate return for the outlay on these vessels, and is the increase in speed which has been obtained sufficient justification for the very great increase of size?

It appears difficult as the size and speed increases to increase the fuel capacity in proportion, and consequently the price paid for speed is not only the increased monetary cost but a diminution of the radius of action. In a previous article—see "The Engineer" of January 10th—we pointed out that the "Tribal" class compare unfavorably with the earlier 30-knot destroyers in this quality. In the *Swift* the deficiency is even more glaring. The oil capacity of this vessel is given in the estimates as 180 tons, which at full speed will give a radius of action of under 300 miles, while at 13 knots it will be under 1,000 miles. Possibly provision is to be made for additional stowage above the 180 tons which is the capacity at load draught, otherwise it is difficult to see what possible use a craft with such a limited radius of action can have. The results which have been obtained are, as we pointed out in

the article previously referred to, very gratifying; much valuable experience has been gained, and in this respect the vessels so far completed have fully justified the expenditure upon them. It must, however, be patent to every intelligent observer that we have in the later vessels reached a point, if we have not already gone beyond it, where the gain in speed is no longer commensurate with the cost of obtaining it, both in money and diminution of radius of action, and we shall be surprised if the sixteen new destroyers to be commenced under this year's program do not show that this fact has been appreciated.—"The Engineer."

UNDER-WATER ATTACK OF SHIPS BY GUNFIRE.

As a result of the trials against the *Hero*, the British Admiralty is now about to undertake a series of experiments with the object of ascertaining whether the system of artillery attack offering the greatest prospects of success is not one which aims at placing high-explosive shells below the actual waterline of the vessel attacked; and if the result of the experiments should be to prove that such a system is a good one, it will at the same time be obvious that the best place for the main armor belt of the attacked ship is rather in the high than the low position.

The trials, which are to be carried out on the obsolescent battleship *Revenge* by the staff of the Whale Island Gunnery School at Portsmouth, have been decided upon as a result of the sinking of the *Hero* in the trials to which reference has already been made. The *Hero* was fired at on four separate occasions by battleships and armored cruisers of the Channel Fleet, and after the first bombardment she sank in about twenty-five feet of water, so that all her upper works still remained visible. After the firing, the ship was visited by a large number of officers and gunnery experts, but their examination utterly failed to show any reason for the vessel sinking. No armor-piercing projectiles were used in the trials,

and the thick protection of the *Hero* was unperforated, while, so far as could be ascertained, no shot had entered above the belt and been deflected through the bottom. This could hardly have been the case, as the protective deck also was unperforated.

The theory put forward to account for the vessel going down is that a shell filled with a high-explosive charge struck the water some distance short of the ship, descended some feet below the surface of the water, and finally brought up against the unprotected side below the bottom edge of the waterline armor belt. The idea was put forward by a non-gunnery officer, and was at first scouted by the experts, who, as it happens, have made little if any study of the questions affecting ricochets.

Now, however, the theory is to be put to the test. The battleship *Revenge* is to take out to sea a specially constructed target, which will have a large proportion of its area under water. Firing will be carried out at various ranges, from 1,500 yards upward, and at each range a series of shots will be fired, the object being to discover how far short of the target the sights must be adjusted to insure the shot striking at a sufficient distance below the waterline to escape contact with the main belt of armor.

If the experiments are successful, that is, if they show that this method of under-water artillery attack is feasible, there is no doubt but that it will be fully developed; for the effect of a high-explosive shell striking below the water level would be much the same as that of a torpedo. Even if such a shot did not sink the vessel struck, the inrush of water would considerably impair her stability. The damage occasioned by the same shell striking above the waterline would not be nearly so great; from which it will easily be seen that for a battleship to have the greater part of her main belt below water may prove rather to be an advantage than otherwise, especially if, as is the case with modern American vessels, there is a good secondary protection above the main belt. Besides, a submerged belt may conceivably prove a defense against torpedo attack.—"Scientific American."

PRIVATE AND DOCKYARD SHIPBUILDING.

It is a self-evident proposition that our principal private shipbuilding yards are able to build warships quite as cheaply as the Government dockyards, and it is practically certain they are also in a position to construct ships at a lower cost than is incurred by the State shipyards. Everything is in favor of private enterprize in this respect, and if it had not been for the desire to exercise a check upon the amounts of tenders submitted by the firms, it is probable that the Government dockyards would not have been expanded to their present dimensions, or that they would be non-existent as State establishments. The yards would be available all the same, but they would be otherwise owned. The private yards, besides being advantageously situated for the provision of such raw materials as they do not themselves produce, construct the hulls and manufacture the plate and machinery, whereas the Government yards are dependent upon the purchase of the whole of the materials and equipment, which have to be transported over considerable distances to the dockyards at a large outlay in cost of carriage. The circumstance that foreign Powers place their orders largely with British firms bears eloquent testimony to the economy and efficiency with which the latter are accustomed to build vessels of every description, and it is probable that, with the exception of those nations which undertake construction on their own account, the whole of the requirements of the remainder of the world would be met by British yards if certain political and financial influences did not tend to divert a portion of the warship construction to other countries. Perhaps the case for British industry was never more concisely set forth than was done by Sir William H. White in the course of Cantor lectures delivered before the Society of Arts in 1906. The lecturer stated that "the construction of warships in this country costs less than that abroad; our resources in shipbuilding, engineering, armor and armament are so much greater than the corresponding resources in any foreign country, that the speed at which construction can be carried out is greater than that which can be

attained abroad." This statement, which was repeated in the following December in a comparison of British and foreign warship building capability that was published in the columns of the leading London newspaper, undoubtedly represents the position of affairs today, notwithstanding developments in the producing capacity of certain other countries.

The pronouncement made by the former Chief Constructor to the Admiralty forms somewhat of a contrast to the statement recently published by Lord Brassey, who, in the course of a letter on naval expenditure and administration, remarked that "if we have lost the advantage we once had in rate of building and cost of construction, we still possess unrivalled resources as shipbuilders." It is impossible to place upon the shoulders of private enterprize responsibility for any decline in the rate of building warships, as the lack of Government orders removes this matter entirely from the control of the shipyards; but the inference that the advantage in point of cost of construction has passed away from the British yards is certainly as unfortunate as it is incorrect. If we possess, as we undoubtedly do, unrivalled resources as shipbuilders, in what particular respect have we lost ground on the score of economical production? The private shipyards are still situated in the same positions, and their capacity for turning out warships has not only not been in any way impaired, but it never was on such a high plane of efficiency as at the present time. If the expenditure on construction is higher than it was a few years ago, the explanation is to be found in the increased cost of materials and higher wages. But as similar conditions prevail in other countries it is difficult to understand how it can be suggested that we have lost any advantage in the cost of construction. Any augmentation which has been experienced in the United Kingdom has been reproduced in other countries, whilst at the same time the latter, generally speaking, labor under the disadvantage of having to transport most of their raw materials and manufactures, exclusive, perhaps, of boilers and engines, over a distance that is considerably greater than in the case of the United Kingdom, excepting,

of course, the Royal dockyards. Lord Brassey is, however, on safer ground when he asserts that every ship we require for the Navy can be as well built by private firms as in the dockyards. The noble lord would, perhaps, not have been incorrect if he had remarked that the experience gained by the private yards, both on the construction of warships for the British Navy and for various foreign navies, tends to justify a claim that they are better able to deal with this class of work than the State dockyards.

The considerations already set forth have been suggested by a perusal of the Dockyard Expenses Accounts for the year 1906–7. At first sight it would appear from the general summary of aggregate expenditure as compared with estimates that whilst the direct charges for new construction undertaken in that year were slightly in excess of the estimates in the case of dockyard-built ships, the outlay on vessels constructed in private yards was considerably less than the original estimates. But on referring to the report of the Comptroller and Auditor-General we find a comparison of dockyard and contract results which purports to show that private enterprize is at a disadvantage as contrasted with the Government dockyards. For instance, a table indicates that the battleships *Dreadnought*, *Africa* and *Britannia* were built in the Royal dockyards at a total of £34,000 less than the original estimates, but the *Hibernia* involved an increased outlay of £16,000, thus leaving a balance of £18,000 in favor of the Government yards. On the other hand, the first-class cruisers *Achilles*, *Cochrane* and *Natal*, which were contract built, are returned as having resulted in a total expenditure of £157,000 beyond the amount of the original estimates. The report, in commenting upon the table, states that "the actual expenditure was less than the original estimate in the case of the dockyard-built ships, and greater in the case of those built by contract." This statement has, however, to be read in the light of the remarks made by the Admiralty in regard to the expenditure on each of the vessels. Thus the revised estimates for the three cruisers amounted to £141,000 more than the

original estimates, this reducing the excess of these vessels to merely £16,000. The Admiralty offers no explanation for the variations between the original estimates and the actual expenditure on the cruisers, and it is doubtless to be found in the alterations which are frequently made during the construction of the vessels. That this assumption is correct is fairly suggested by the observations made respecting the work actually done in 1906–7. During the year the outlay on the *Achilles* was £31,000 less than the estimates, and £6,000 less in the case of the *Natal*, whilst the expenditure on the *Cochrane* was £8,000 higher, owing to alterations and additions ordered during the building of the vessel. If explanations were also given for the total excess of the actual outlay over the original estimates or over the comparatively slight augmentations indicated by the revised estimates, it is probable that the suggestion as to cheaper construction in the dockyards would not have been made, seeing that the exceptional facilities enjoyed by the private shipyards, as previously mentioned, place them at an advantage over the Royal dockyards. —"The Engineer."

THE CRUISER PROBLEM.

The armored cruiser of the 1908–09 program is, it is presumed, of the *Inflexible* class, though rumors of a new departure have been plentiful. As in battleships, so in cruisers, multiplicity of types is not an advantage, and four ships of excellent but varying and non-homogeneous types are probably not equal to four of less individual power but homogeneous.

The ideal cruiser has been defined by Commander Hovgaard as a "battleship made extra large so as to secure increased speed without any sacrifices." The *Inflexible* type, of course, falls short of this, just as it also falls short of another very practical ideal for an armored cruiser—"a battleship that gives up some of its guns for speed." Such a cruiser, after losing some of its speed by damage in action,

could revert to the line as a battleship minus a gun or two. Sufficient attention was not, perhaps, however, directed to the fact that the *Inflexibles* fill a distinct ideal of another sort. They are "battleships which sacrifice some armor to speed." The point to be made in favor of this is as follows: The ships have sufficient speed to be able to avoid engagement whenever they please—unless, of course, cut off in narrow seas. But their gun power is such that even the finest battleships would hesitate to engage them, and on this account they could do a very great deal in the way of heading off a battle fleet which, were they "battleships with guns sacrificed to speed," they would hardly be able to do. A consideration of these two sides of the problem shows clearly enough that the Hovgaard ideal is the only really sound one for all eventualities, although the immense cost stands in the way of the construction of such vessels so far.

There is still a school of thought which insists that the vessel with moderate guns and moderate protection is the logical cruiser, even though paper demonstration of her utility may be difficult. There is one argument in connection with this school that is not often advanced, but which, none the less, has considerable potency, and that is, that however invincible any projected cruiser may be, it will never be long before something more recent comes along beside which she is relatively of small account.

The school referred to would postulate as its first requirement "numbers"—"numbers at all costs." It is, of course, patent that numerical superiority can only be secured by the sacrifice of invincibility to start with. Those who hold this view would, of course, argue that, given the necessary numbers, so long as the cruisers possess guns sufficiently powerful to damage an enemy, combination will give them all other necessary superiority upon occasions when it is required. This line of thought has few exponents now-a-days, but there is probably more forceful logic behind it than appears at a casual glance.

Without seeking to draw any particular moral from them,

these points may be mentioned in the hope that they may serve to concentrate attention upon the extremely delicate problem that is before constructors when armored cruisers are under consideration.—"The Engineer."

AMERICAN TURBINES FOR THE JAPANESE ARMORED CRUISER *IBUKI.*

Two large turbines now being built in the shops at the Fore River Shipbuilding Company should possess a special interest for American readers. They will form the motive power for the latest of the new Japanese armored cruisers, the *Ibuki*, a fine vessel of 14,600 tons displacement and 22 knots speed, which is now nearing completion at the yards at Kure, Japan. The significance of these engines lies in the fact that they are the first large marine turbines to be installed in a Japanese warship; and it is a distinct indorsement of the progress made in this country in the development of the turbine that such an astute people as the Japanese should have selected the Curtis type for the motive power of so valuable a ship. The *Ibuki* and her sister ship, *Kurama*, are identical vessels, with a length of 450 feet, a beam of 75½ feet, and a mean draught of 26 feet. We understand that the *Kurama* is being equipped with reciprocating engines, and, therefore, in these two vessels will be afforded an opportunity to test the respective efficiency of the two types of motor.

The later ships of the Japanese Navy, which are being built by the Japanese themselves, are distinguished, like the ships of our own Navy, by the unusually heavy batteries which they carry. Thus, the *Ibuki* mounts four 45-caliber 12-inch guns two in turrets; eight 45-caliber 8-inch guns in eight single turrets; and fourteen 4.7-inch guns, ten of them in a central battery and four in casemates, two at the bow and two at the stern. The ships are protected by a 7-inch belt and a 2-inch armor deck. The 12-inch-gun turrets have 7 inches protection, the 8-inch-gun turrets 6 inches pro-

tection and the 4.7-inch guns are mounted behind 5 inches of armor.

The motive power of the *Ibuki* consists of two turbines, which are designed to develop a normal horsepower of 24,000, sufficient to drive the *Ibuki* at 22 knots speed. They are intended, however, to develop a maximum overload horsepower of 27,000, which should suffice to give a speed of nearly 23 knots. The rotor is 144 inches in diameter. The casing has an outside diameter of 14 feet and a length over all of 17 feet. The weight of the two turbines together is 360 tons.

Each turbine consists of a cast-iron cylindrical casing divided by dished diaphragms into a series of separate compartments. In each compartment or "stage" there is a separate wheel, which carries on its periphery three rows of moving buckets (for reasons later described the first wheel has four rows). The wheels are all mounted on a hollow steel shaft carried by two bearings. Where the shaft passes through the diaphragms they are provided with bronze bushings having a small clearance, thus preventing appreciable steam leakage from one stage to the other. Where the shaft passes out through the ends of the casing it is provided with carbon stuffing boxes, which prevent steam leaking out at the ahead end, or air leaking in at the back end where a vacuum exists.

The stuffing boxes are supplied with steam in the space between the carbon packing, to prevent air leaking in and lowering the vacuum. They are also drained to the fourth-stage shell.

Cast-steel steam chests for ahead and astern running are attached to the front and back casing heads, and are flanged for the main steam pipes. The nozzles for each stage are bolted to the diaphragms, the diaphragms having steam-port openings cast in them to allow the steam to pass through to the nozzles.

Maneuvering is accomplished by means of two lever-operated balanced throttle valves, each taking steam from the

main steam pipe, and one delivering to the ahead steam chest and the other to the astern steam chest. There are seven ahead wheels and two reverse wheels. The reverse wheels are mounted in the after end of the casing, and under ordinary ahead running they are in a vacuum and, therefore, do not waste power by steam friction. They are similar to the ahead wheels, except that the blades are reversed. To reverse when going ahead, the ahead-throttle valve is shut and the reverse-throttle valve opened, which is easily and quickly accomplished by the operating levers of the two throttle valves.

Drain pipes are provided, connecting each stage with the next, so the condensed steam in any stage will pass to the next one of lower pressure, and there give up a part of its heat to do useful work. The exhaust chamber drains to the condenser and the discharge is assisted by a small steam ejector. A regular marine thrust bearing is attached to the forward end of the turbine shaft. In addition to taking the propeller thrust, this bearing also maintains the proper axial position of the rotor, so that the axial clearance of the blades is correct. This clearance is one-tenth of an inch on the first wheel and increases to one-quarter of an inch on the seventh wheel. The thrust is put at the forward end, so that any unequal expansion of the shaft and casing will be allowed for at the aft end, where the clearance is largest. This axial clearance is very ample to allow for all unequal heat expansion that may occur and any mechanical irregularities, and leave sufficient leeway for adjustment.

To allow for the increased volume of the steam as it expands in passing from stage to stage at lowering pressures, the lengths of the blades are increased and also the arc of the nozzles is increased, thus giving greater area of passage in each succeeding stage. Also, in any one stage, the blade lengths are increased in each succeeding row, because the velocity falls as the steam passes from row to row, although it is at practically constant pressure throughout the stage.

In order to keep the pressure in the shell as low as possible,

the pressure distribution is arranged so that one-fourth of the available energy of the steam is expended in the first stage and one-eighth in each of the other stages. This requires the first-stage nozzle to be of the expanding type, but all the other nozzles are of the parallel-flow type. Also, the first-stage wheel is provided with four rows of buckets instead of three, as on the other wheels, since the greater energy drop produces greater velocity of the steam jet from the nozzles, which requires more rows of buckets to properly absorb the energy at the bucket speed used. This arrangement makes all the ahead wheels except the first operate under eight-stage conditions. The principal advantages of the Curtis design of marine steam turbine are as follows: small number of blades; large clearance around blades; strong mechanical construction of blading; economy at reduced speed, without cruising turbines; interior of shell not subjected to full steam pressure; low revolutions for given horsepower; absence of dummy pistons and packing.

The small number, large clearance and strong construction of the blades make blade stripping practically impossible, and no case has occurred.

By the use of valves on the nozzle openings of the diaphragms, the proper steam-pressure distribution can be maintained at reduced steam flow, thus keeping up the economy at low speed of vessel, except, of course, for the unavoidable loss due to lower revolutions and dispensing with cruising turbines.

Full steam pressure comes on the steam chest only, which is a comparatively small steel casting. The greatest pressure in the turbine shell is less than one-third the working steam pressure. This permits high steam pressure to be used, and large turbine diameter in comparison to the power. It also reduces expansion difficulties.

The comparatively low revolutions permissible for a given power without sacrifice of economy or excessive weight allows the twin-screw arrangement to be used instead of three or four screws. Also, other conditions being the same, lower

revolutions will give a higher efficiency of the propeller. Low revolutions also permit the use of turbines in comparatively (for turbine vessels) low-speed vessels.

Absence of dummy pistons and their packing eliminates the leakage of high-pressure steam and makes the economy independent of any adjustments, so that the initial economy will be maintained continuously and will not be affected by any wear.—"Scientific American."

THE COMBINATION SYSTEM OF RECIPROCATING ENGINES AND STEAM TURBINES.

Extract from a paper read before the Institution of Naval Architects, April 9, 1908, by the Hon. C. A. Parsons, C. B., F. R. S., D. Sc., M. A., and R. J. Walker.

In the early years of steam-turbine design and development it became apparent that the turbine engine was capable of economically dealing with ratios of expansion far beyond the reach of any reciprocating engine, whose limitations in this respect had been experimentally determined by many investigations. In 1889 the first condensing turbine of about 100 horsepower was designed for an expansion ratio of 100 by volume, the expansion being effected in two turbines of the double parallel-flow type, the low-pressure turbine taking steam from the exhaust of the high-pressure at atmospheric pressure, and expanding it down to 1 pound absolute. The striking feature presented by this design was the very high estimated efficiency of this low-pressure portion. A separate low-pressure turbine was not, however, actually constructed till some years later.

In 1894 a patent was taken out for the "combination" of a reciprocating engine with a steam turbine, whose object was "to increase the power obtainable by the expansion of the steam beyond the limits possible with reciprocating engines." The previous treatment of the steam is, of course, immaterial, provided that its condition of pressure and wetness on reaching the engine are known. The first instance of a separate

turbine worked from the exhaust of other turbines was in the *Turbinia's* machinery in 1897; the pressure at entry of her low-pressure turbine was about 9 pounds absolute and the exhaust 1 pound absolute. The slip ratio of her three shafts showed that the low-pressure turbine developed about one-third of the total horsepower obtained from the steam at 160 pounds pressure, agreeing closely with calculations.

In the year 1902 the combination of reciprocating engines exhausting into turbines was first put to a practical test in His Majesty's destroyer *Velox*. In this vessel two small reciprocating engines were fitted for cruising purposes, of such power that, in combination with the main turbines, they would give an economical consumption at the speeds of 11 to 13 knots, the usual cruising speeds at the time the *Velox* was built. The arrangement of machinery consisted of one main high-pressure and one low-pressure turbine on each side of the vessel, each driving a separate shaft, or four shafts in all. A small reciprocating engine was coupled at the forward end of each of the low-pressure turbines. For speeds up to about 13 knots steam was admitted to the two reciprocating engines and expanded down to about atmospheric pressure; it then passed through the high-pressure, and thence through the low-pressure, turbines to the condenser. This combination gave excellent results at these cruising speeds. For speeds above 13 knots, however, the reciprocating engines had to be cut out and steam admitted to the turbines alone. With the advance of naval efficiency, the cruising speeds of war vessels have been increased, and in vessels subsequent to the *Velox* additional high-pressure turbines have been fitted, an arrangement which permits of good economy over a wide range of cruising speeds.

It may be said that perhaps the most important field for the combined system of machinery as applied to marine propulsion is for those installations where the designed full speed of the vessel falls below the range suitable for an all-turbine arrangement, the reciprocating engine working in the region of pressure drop where the conditions are best suited for it,

and the turbine utilizing that portion of the expansion diagram which the reciprocating engine is not able to utilize efficiently. It is generally well known that an all-turbine arrangement has not been advocated by us for ships where the designed speed falls below 15 or 16 knots, excepting in some special cases, such as yachts; and for vessels of moderate or slow speed the combination system of machinery appears to be eminently suitable.

In a good quadruple-reciprocating engine the steam is expanded down to the pressure of release, about 10 pounds absolute, and gains in economy as the vacuum is increased up to about 25 inches or 26 inches; whereas in a turbine it is possible to deal economically with very low-pressure steam, and to expand this low-pressure steam to a low absolute pressure corresponding to the highest vacuum obtainable in turbine practice.

In a combination system the most suitable initial pressure for the turbine, or the dividing line between the reciprocating engine and the turbine, will greatly depend upon the conditions of service of the particular vessel taken. The reciprocating engine, or engines, could be designed to exhaust at a pressure of between 8 pounds and 16 pounds absolute, or even at a slightly higher pressure, if necessary, to meet the conditions required. From an estimate of the theoretical efficiency under the various conditions of pressure, as set forth in the following table, it would appear, apart from any practical considerations, that there is nothing to choose between an initial pressure at the turbine of between 7 pounds and 15 pounds absolute, any pressure within this limit appearing to give the most economical result.

......	Initial pressure turbine.	Reciprocating engine back pressure.	Theoretical B.T.U. per pound of steam.		
			R.E.	Turbine.	Total.
Assuming 200 pounds absolute at reciprocating engine to 28-inch vacuum at condenser.	15	16	178	142	320
	12½	13½	189	131	320
	7	8	218	100	318

In the case of a vessel which runs on service continually at or about her designed full speed, an initial pressure of about 7 pounds absolute at the turbine appears most suitable. In a vessel which does part of her running at the designed power and part at a considerably reduced power, it is desirable to design the turbines so that the initial pressure would not fall below 7 pounds absolute when running under the lower conditions of power.

......	A Twin quadruple reciprocating engines.	B Three-cylinder triple-expansion twin reciprocating engines, with two low-pressure turbines in parallel.	C Four-cylinder triple-expansion twin reciprocating engines, with one low-pressure turbine.
Dimensions of reciprocating engines.	$\frac{25.\ 36\frac{1}{4}.\ 51\frac{1}{4}.\ 75}{55}$	$\frac{27.\ 42.\ 66}{48}$	$\frac{26.\ 39.\ 46.\ 46}{42}$
Revolutions of reciprocating engines.	84	85	100
Piston speed of reciprocating engines	770	680	700
Boiler pressure, pounds	213	213	213
Estimated pressure at H.P. receiver, pounds	200	200	200
Initial pressure turbines, absolute	...	7	7
Vacuum in condenser, inches	26	28	28
Steam consumption, main engines only, pounds per hour	95,000	95,000	95,000
I.H.P. reciprocating engines	7,300	6,300	6,300
Estimated equivalent I.H.P. of turbines	...	2,000	2,000
Total I.H.P.	7,300	8,300	8,300
Per cent. increase power	...	13.7	13.7
Estimated speed, knots	15.5	16.2	16.2
Steam consumption, pounds per total I.H.P. per hour main engines	13	11.45	11.45
Steaming weight of engines and boilers (reciprocating engines), tons	...	1,430	1,455
Weight of turbine installation, tons	...	65	70
Total steaming weight, tons	1,560	1,495	1,525
Revolution of turbines	...	480	320

It may be of interest at this stage to consider the disposition of the turbines in combination with reciprocating engines on board ship. The arrangement of the turbine, or turbines, depends greatly whether the vessel is to be fitted with single

or twin-screw reciprocating engines. With a single reciprocating engine one turbine, two turbines in "series" or two turbines in "parallel" could be fitted, each turbine driving a separate shaft in addition to the reciprocator shaft. With twin-screw reciprocating engines an arrangement of one turbine in the center of the vessel, two turbines in "parallel," or two turbines in "series" could be adopted. The arrangement which seems to commend itself generally to shipowners and builders, where twin-screw reciprocating engines are fitted, is the arrangement with the turbine on the center shaft.

Owing to the rapid development of the turbine industry for high-speed work and the attention which was, in consequence, paid to this branch of the business generally, the development of the combination system fell more into the background than its merits and the wide scope of its application would seem to have deserved.

About two years ago, at the suggestion of Sir William White, designs were prepared of a combination system as applied to the intermediate type of liner of moderately large power and speed, and since that time numerous designs have been prepared for various types of vessels of speeds ranging from 13 to 16 knots.

By the courtesy of Messrs. Swan, Hunter and Wigham Richardson, who, for a considerable period, have taken much interest in this combination of machinery, the figures in the table are given of the comparative sizes of engines, power, etc., of the "combination" as compared with twin-quadruple engines, for a proposed steamer of 490 feet in length, 13,600 tons displacement, 7,200 indicated horsepower and 15½ knots speed.

In the combination proposals set forth in columns B and C in the above table it may be mentioned that in this particular inquiry the shipowners wished to have the advantage of the additional power and increase in speed of the vessel on the same coal consumption as for the twin-quadruple engines. In some instances an increase in speed might not be desired, in which case the boilers and engines could be reduced in

size by the estimated amount of saving in consumption, so that the total indicated horsepower of the combination did not exceed that required with twin-quadruple engines. This would considerably reduce the total weight of machinery, and also the bunker capacity for a given distance. This saving in the weight of the machinery and in the bunkers would enable the vessel to carry an equivalent addition in dead-weight cargo. Then, again, if we take the indicated horsepower of 8,300 for the combination, and assume that quadruple engines and boilers were required to give an equivalent power, the extra total weight of the machinery would be, roughly, 160 tons, in addition to an increase of about 12 per cent. in coal consumption for the same power.

In the arrangements for maneuvering in and out of port, suitable arrangements are made for changing the flow of steam of the low-pressure cylinder exhaust of the reciprocating engine from the turbine to the condenser. This can be done in two or three ways. One method is to have an ordinary change valve of the piston type, or ordinary double-beat spring-loaded valve actuated by links connected to the weigh shaft of the main engine, which would automatically change the flow of steam to the condenser when the engine was reversed. With this arrangement, when going ahead on one side of the ship, the steam from the reciprocating engine would flow through the turbine, but there does not appear to be any objection to this, even if we consider the twin-screw reciprocating arrangement with a single turbine on the center shaft. It might be rather an advantage, than otherwise, to allow the steam from the engine going ahead to pass through the turbine, as the center propeller revolving would accelerate the feed of water on the rudder and augment the turning power of the vessel.

Another method would be to work these valves independent of the main engines, actuated by an hydraulic engine or by an ordinary steam-driven reversing engine. With this arrangement the low-pressure turbine would be cut out altogether and the reciprocating engine would exhaust to the

condenser, whether going ahead or astern during maneuvering.

Enough has, perhaps, been said as to the general arrangement and estimated economy obtainable in the combined system, and now it may be of interest to refer to the general application of the system.

The development of the combination is already rapidly taking place on land, where the exhaust steam from non-condensing engines, especially the winding engines at collieries and rolling and mill engines, is being utilized in low-pressure condensing turbines. There are, at the present time, some twenty-four of these installations of the Parsons type delivered, working and under construction, ranging from 125 kilowatts to 1,250 kilowatts, representing a total brake horsepower of about 17,000. In most cases the exhaust steam is supplied to the low-pressure turbine at 15 pounds absolute pressure and a vacuum of 28 inches, and under such conditions about an equal amount of power can be obtained from the turbine as from the non-condensing reciprocating engine, thereby doubling the power of the plant without any further consumption of fuel. From several tests made with these exhaust turbines on land, a consumption of about 34 pounds per kilowatt-hour can be obtained in a 500-kilowatt machine, with an initial pressure of 15 pounds or 16 pounds absolute to 28-inch vacuum.

In regard to marine installations, the combination is being fitted to a large vessel at present under construction at the works of Messrs. Harland and Wolff for the Montreal trade of the Dominion Line. The arrangement of machinery in this vessel is substantially as described in column C of the Table previously referred to, viz: twin four-crank triple-expansion engines exhausting into one low-pressure turbine driving the center shaft.

Messrs. W. Denny & Brothers are also at present building a vessel for the New Zealand Shipping Company, which is being fitted with the combination system of twin triple-expansion engines and one low-pressure turbine. This vessel is an exact repeat of two other vessels Messrs. Denny have built for the same owners, except as regards type of engines.

In addition to the above, the Turbinia Works, in conjunction with Messrs. A. Stephen & Sons, of Glasgow, are fitting the combination system to the yacht *Emerald*. In this vessel, which was one of the first to be fitted with an all-turbine arrangement, it is intended to make some modifications to the existing arrangement of machinery by introducing a reciprocating engine on the center shaft in lieu of the high-pressure turbine at present in the vessel. This engine will be of the high-speed enclosed self-lubricating type, and is now being constructed by Messrs. J. S. White & Co. It is designed to exhaust into the two low-pressure turbines at about 15 pounds absolute pressure, the dimensions of the cylinders being 12½ inches, 19 inches and 30 inches, by 18-inch stroke, and revolutions about 350. It is expected that this vessel will be ready for trials in about four months' time.

TURBINES AND PROPELLERS.

It was almost inevitable that turbines should come in for most attention at this year's very successful session of the Institution of Naval Architects. During the past year there have been evolved data of a suggestive nature. The efficiency of the turbine is now placed beyond doubt; but, as is happily the case in all scientific pursuits, there are indicated directions in which progress is possible in subsidiary or auxiliary items in the complex problem of ship propulsion. Thus questions affecting steam generation, superheating, condensation and propeller design and the methods of arriving at satisfactory forms of hull have been brought more prominently to the front than formerly, as a consequence of the special requirements of the turbine; and on these topics papers were read and discussions took place, which we are fully reporting in the belief that the points raised must influence future marine practice. At the same there were interesting contributions on the construction of ships; but these, although in some respects original, can scarcely influence greatly the shipbuilding practice of the day.

The most conclusive paper, and the one which was awaited with greatest interest, was that on the *Lusitania* turbine performances. It quite met expectation, and it nailed many misstatements to the counter, so that its author, Mr. Thomas Bell, of Messrs. John Brown & Co., Limited, is to be congratulated. In the first place, it proved that the turbines of this ship, as well as of her consort, the *Mauretania*, have a high efficiency. From the data given we have worked out the thermo-dynamic efficiency as 62.6 per cent. at 68,850 horsepower, which is very favorable, and compares with 61.3 per cent. at 23,000 horsepower in the *Dreadnought*. The coal consumption for all purposes on the *Lusitania's* best Atlantic trip was under 1.5 pounds per horsepower per hour, when running at full speed. Consistent with all experience, the coal consumption steadily increases with decreased speed, the rate for 15 knots being 2½ pounds; but the Atlantic liner always runs at full speed, so that we have ideal conditions for the application of the turbine. A pertinent question by Admiral Henderson enabled Mr. Bell to state definitely that the total coal consumption was quite in accordance with expectations. The bunker capacity is 6,300 tons, and the vessel can steam at 25 knots across the Atlantic and have still enough coal to carry her 500 nautical miles farther. At full speed her radius of action is thus about 3,400 nautical miles. The total steam consumption of all the machinery is 14.46 pounds per horsepower hour, but of the steam turbines only 12.77 pounds, which latter figure compares with 13.4 pounds in the *Dreadnought* and 13.6 pounds in the *Amethyst*. But on these Atlantic liners, as Mr. Bell pointed out, the demand for hot water and for steam for auxiliaries is abnormal. These results are all very satisfactory.

The propulsive efficiency works out to about 50 per cent. at full speed. This is about the same as the *Dreadnought*, but is rather less than in the case of twin-screw reciprocating-engine propelled ships. As we have time and again pointed out, the important question of the day has reference to the propeller. As one speaker remarked, it would be all right if one could design turbine or propeller without reference to the

other. The higher thermo-dynamic efficiency of the turbine justifies a forfeiture of some part of the efficiency of the propeller. In the turbine a high rotational speed is aimed at, as it is desirable that the blade speed should have a high ratio to steam speed. In the propeller the peripheral speed should be minimized and the thrust moderate, otherwise there is possibility of loss. A compromise between these conflicting elements is aimed at.

The further study of the propeller problem is being followed with characteristic care. So far the results in the case of the two Cunard liners are good, and we are sure that, as Mr. Andrew Laing put it, when the ships, staff and stokers settle down both ships will exceed their 48-hours' trial performance. Meanwhile the views put forward by Dr. Froude and Mr. Parsons as to 20 to 22 per cent. being a preferable ratio of slip than 15 to 17 per cent., and as to the relative efficiency of different forms of blades, are important.

The question raised in connection with the trials of the turbine-driven destroyers of the *Tartar*, or so-called "Tribal," class is quite different, but here also the turbine has proved very efficient. Although not brought out at the meeting, we believe the steam consumption was about 14 pounds per horsepower hour in this case also, as compared with nearly 20 pounds in vessels of the same type having reciprocating engines. The speed problem here was associated with the depth of water over the ground traversed by the boats. This point was, unfortunately, complicated by others which are not germane to the scientific question involved. No one disputes the fact that under Admiralty conditions, and on a measured mile approved by the Admiralty, the *Tartar*, *Mohawk* and other vessels have, while in a trim according with specified requirements, achieved speeds ranging up to 35.36 knots in the case of the *Tartar*. That was the speed registered by the Admiralty staff on board. We speak thus decidedly, as there may be misunderstanding as a result of the discussion at Wednesday's meeting of the Institution, and reported in last week's issue. This explanation, too, is important owing to the tendency for British writers and speakers to assist foreign critics

in decrying British results. We manufacture largely for foreign owners, and it is important, from the commercial point of view, that there should be no possibility of misunderstanding. This is altogether apart from the utilizing of an institution which is now almost international in its membership and in its proceedings for the advancement of British trade interests. French, Italian and other Continental writers have been putting forward the need for scrupulous accuracy in the discussion of results so as not to affect foreign clients to the disadvantage of national trade, and this necessity should not be neglected in this country. The scientific point regarding the speed of the destoyers must therefore be dissociated from the commercial question.

The subject of the influence of depth of water on speed is one of great importance. The 25½-knot destroyers of the "River" class had difficulty in getting the designed speed except in deep water, and the Skelmorlie mile on the Clyde was preferred by some firms for its 40 fathoms of water to the Maplin Sands mile with its 10 fathoms. As has before been shown by Mr. Yarrow, this relation of depth of water to speed and form is a most difficult one, and in view of the disparity in results got with the destroyers of the 33-knot class on the measured mile at Skelmorlie and those tried on the Maplin Sands, the Admiralty have very advisedly decided to have a series of trials with the *Cossack*—the first of the new destroyers of the class to be completed—on the principal measured miles in the country. The conditions will be as nearly as possible identical, the only variant being depth of water. These data will be a most useful supplement to the splendid results already recorded for this type of vessel.

The combination of reciprocating engines and low-pressure turbines, the latter to take the exhaust from the former, has been adopted on land stations, particularly where the load on the piston engine is intermittent; and it is gratifying to note that three steamers are now to be fitted with a combination system. This, as Mr. Thomas Bell pointed out, is a development corresponding with triple and quadruple-compounding, as it similarly improves the temperature range. The question

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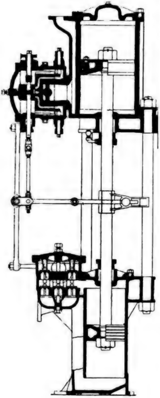
at issue seems to be whether the engine to be used should be compound or triple-compound. There are even those who advocate simple engines; but the range of expansion from 200 pounds or 210 pounds boiler pressure might be too great for one cylinder. There are other problems associated with difference in shaft speeds for the two types of machinery, with the exclusion of oil from the turbines.—"Engineering," April 17, 1908.

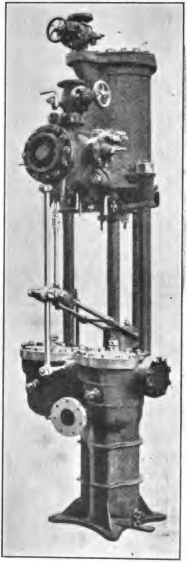
FEED PUMPS FOR THE ITALIAN NAVY.

A complete set of main and auxiliary feed pumps for the Italian cruiser *San Giorgio* have recently been provided by Messrs. Henry Watson and Sons, of High Bridge Works, Newcastle-on-Tyne. The pumps, which are shown in the engravings on page 467, are of the single-cylinder direct-acting Admiralty type, and have 10¾-inch barrels by 24-inch stroke. They are fitted with balanced valves and special self-adjusting buckets. The duty of each pump when drawing through a suction pipe of 160 feet length with a lift of 7 feet was specified as 50 tons per hour, against 255 pounds boiler pressure at fourteen double strokes per minute and exhausting against 10 pounds back pressure. The actual results obtained on a series of exhaustive tests run under working conditions—in the presence of Major Girola, of the Italian Admiralty—were, we understand, considerably in excess of the specified duty, and a high pump efficiency was obtained at both low and high speeds. The steam consumption was not specified, but although the trials were run before the cylinders and pipes were lagged, the steam used was taken to an auxiliary condenser and measured. The results obtained at the trials mentioned are given in the table below.

Revolutions per minute.	4	6	8	10	12½	14½	15	16	17
Gauge pressure at cylinder	148	152	155	170	172	173	175	176	178
in discharge	255	255	255	255	255	255	255	255	255
Tons pumped per hour	14.92	23.0	30.75	39.5	50.0	58.5	59.6	63.25	67.5
Pump efficiency per cent	92.75	95.0	95.5	98.0	99.25	98.2	98.6	98.0	98.5
Steam horsepower	13.0	19.55	26.2	29.5	39.2	45.0	46.5	50.0	54.0
Water horsepower	11.0	16.6	23.1	28.25	35.2	41.5	42.5	45.75	48.5
$\frac{\text{Water h.p.}}{\text{Steam h.p.}}$ per cent	84.5	85.0	88.4	96.0	90.0	92.3	91.5	91.2	90.0
Steam used per I.H.P. per hour, lbs	78.0	73.0	67.8	69.5	62.5	57.3	56.25	54.0	51.4

"The Engineer."





RELATIVE WEIGHTS AND SPACES OCCUPIED BY MACHINERY IN TYPICAL VESSELS.

Name of Vessel.	*Deutschland.*	*Celtic.*	*Glenlyon.*	H.M.S. *Defence.*	H.M.S. *Temeraire*	*Duke of Cornwall.*	S.Y. *Tuscarora.*
Type of vessel	Atlantic liner	Intermediate liner	General cargo	1st-class cruiser	1st-class battleship	Cross-chan'l st'mr	Pleasure yacht
Builders	Vulcan Co.	Harland & Wolff	Scotts', Greenock	engines by Scotts'	engines by Hawthorne, Leslie	Vickers	Scotts', Greenock
Owners	Hamburg-Amercn.	White Star	Gardiner & Co.	British Admiralty	British Admiralty	L. & N.-W. R. Co.	W. Jennings.
L. by B. by D.(mld.) ft. and ins.	662-9 by 67-0 by 44-0	680-0 by 75-4½ by 48-4½	377-0 by 49-6 by 28-9	490-0 by 74-6	490-0 by 82-0	315-0 by 37-0 by 17-6	181-0 by 26-0 by 14-5
Displacement, tons	23,620	33,550	9,782	14,000	18,600	2,830	790
Gross tonnage	16,502	20,880	4,149	...	...	1,540	541
No. of propellers	2	2	1	2	4	2	1
Type of engines	6-cyl. quadruple	4-cyl. quadruple	3-cyl. triple	4-cyl. triple	Parsons' turbines	4-cyl. triple	3-cyl. triple
No. and type of boilers	12 D.E. and 14 S.E.	8 D.E.	2 S.E. cylindrical	24 Yarrow W.T.	18 Yarrow	4 S.E. cylindrical	1 S.E. cylindrical
Working pressure, pounds	220	210	180	250 at engines	170 at engines	180	200
System of draft	Howden's forced	assisted	Howden's forced	closed stokehold	closed stokehold	closed stokehold	closed ashpit
Speed, in knots	23.51	16.0	10.75	23.0	21.0	19.75	13.15
I.H.P. on full-power trial	85,000	13,000	2,400	27,000	23,000 (shaft H.P.)	5,530	1,100
Superficial area per I.H.P.:							
Engine room, square feet	0.139	...	0.428	0.109	0.208	0.165	0.27
Boiler room, square feet	0.286	...	0.31	0.226	0.23	0.24	0.333
Total, square feet	0.425	0.96	0.738	0.335	0.438	0.405	0.60
Total weight of machinery, "Steam up," tons	5,670	2,975	474	2,368	1,890	612	137
Weight as per cent. of displacement	24.0	8.87	4.85	16.2	10.15	21.6	16.7
I.H.P. per ton machinery	6.35	4.37	5.06	11.75	12.17	9.02	8.35
I.H.P. per gross registered ton	2.12	0.62	0.58	...	...	3.58	2.04

RELATIVE COSTS OF DIFFERENT TYPES OF MARINE PROPELLING MACHINERY.

Description.	Rate per I.H.P. (full-power trial).			Rate per ton of Finished weight—"Steam up."		
Merchant vessels, with reciprocating engines and cylindrical boilers:	£		£	£		£
Large ocean liners	6.5	to	7.0	36.5		
Intermediate liners	5.5		6.5	34.0		
Cargo tramps	5.0		5.5	23.0	to	26.5
Cross-channel steamers	5.5			48.0		52.0
Pleasure yachts	7.5			55.0		
Naval vessels, with reciprocating engines and water-tube boilers:						
1st-class cruisers	10.6		11.25	120		
3d-class cruisers	6.5			105		
Destroyers	5.5		6.5	200		225
Battleships, with turbines and Yarrow boilers, per shaft H.P.	11.13		11.35	137		140

THE WEATHERING OF COAL.

By S. W. PARR, Professor of Applied Chemistry, and N. D. HAMILTON, Fellow in Chemistry, University of Illinois. (In connection with the Illinois State Geological Survey.)

The weathering of coal is a subject of perennial interest. Moreover, its importance is not likely to grow less in view of the trend of modern industrial conditions. Almost every circumstance attending the production and use of coal calls for flexibility in the current supply. The seasonal changes in greater temperature, the fluctuating demands for freightage, the periodical disturbances in the labor supply, all argue for the possibility of carrying at certain periods a reserve of fuel to guard against suffering or complete paralysis of industry.

It is not surprising, therefore, to learn of the increasing number of storage plants where coal may be placed in large quantities to supply the needs of great industries which would suffer if from any cause or combination of circumstances a coal famine should ensue. An example of this is the plant of the Philadelphia and Reading Coal and Iron Company at Abrams, Pennsylvania. At this plant arrangements are made for eight piles of coal, each containing 60,000 tons, piled on the ground in the open and equipped with modern facilities for dumping and reloading. The storage plant also of the New York Edison Company at Shadyside, New Jersey, where 150,000 tons of coal are stored in three piles on a bed of cinders in the open, and that of the Lehigh Railroad at Wyoming, New York, with a capacity of 100,000 tons, are but a few of the instances where our industries are resorting to outdoor storage for reserve coal supplies. This method of storing is not only the practice where large quantities of coal are to be taken care of, but there are very few power and heating plants and fuel-using industries that do not find it necessary to pile more or less coal on the ground, at least temporarily, until room can be made for it in the coal shed or boiler house. The practice in vogue in the coal fields, among coal dealers and all consumers of comparatively small quantities varies greatly. In general, however, it may be said that the coal is

either stored in covered iron or wooden bins with slanting bottoms to facilitate its removal, or in ordinary covered bins with earth, cinder or wooden floors, from which it is removed with the scoop. In power and heating plants the placing of the coal bins depends upon the position of the boilers and the method used for firing and transportation of the fuel to the building. The United States Navy, which uses about 250,000 tons of coal yearly, has been equipped with large storing facilities, each compartment in the station at the New York Navy Yards having a capacity of 525 gross tons, with floors of portland cement, roof of iron and side walls of portland cement, sand and anthracite cinders. On board vessels coal is stored in whatever room happens to be available.

Aside from these prevalent methods of caring for coal reserves, the practice of storing coal under water is coming into prominence, but the working out of this plan cannot be said to have gone further than the experimental stage. The English Admiralty has been experimenting with submerged coal, and the Western Electric Company of Chicago has recently built two bins of 4,000 and 10,000 tons respectively below the ground level. The plan is to dump the coal into the bins directly from the car and flood it with water until needed for use, when a crane fitted with grab buckets will lift it to the car again.

As one reviews the literature of the subject it is strikingly evident that well authenticated facts and data are very meager, with much disagreement among those who have presumed to possess knowledge in the matter. There is a general belief that coal does deteriorate, but under what conditions, to what extent, and according to what principles, are certainly open questions at the present time. The following resumé of the statements by various writers will be of advantage in gaining a present knowledge of the situation. There are included also, references which deal with the spontaneous ignition of coal, on account of the close relationship of that topic to the one in hand.

HISTORICAL REVIEW.

After careful experiments, Dr. Richter, in 1868*, concluded that the weathering of coal is due to the absorption of oxygen, a part of which goes to the oxidation of carbon and hydrogen in the coal, and part is taken into the composition of the coal itself; that if the heap becomes warm, either through this process or through any other cause, the action is accelerated, but then falls off and becomes so slow that the changes effected within a year are difficult to estimate; that moisture as such has no direct influence upon the process, apart from the presence of pyrites or from the coal crumbling down more rapidly when wet than when dry, and, therefore, more rapidly heating up. At a later date, he concluded that large coal was less affected than small, not because it had less surface, but because small coal was a more active absorbent of oxygen, and therefore, became more rapidly heated; that airways in heaps would have to be very numerous in order to prevent any rise in temperature.

Haedicke, in 1880†, while assigning to pyrites the leading part in spontaneous combustion, agrees that this hypothesis does not hold good unless the temperature is allowed to rise sufficiently.

Professor Fischer, of Gottingen, as a result of research work prior to 1901†, concludes that storage depreciation and spontaneous ignition are phenomena of oxidation; the part which is played by iron sulphide has been disputed, but the variances that have given rise to the uncertainty are due to the differences between the different sulphides of iron present in coal. Marcasite, for example, he says, is much more weatherable than ordinary pyrites. Actual wetting is much more promotive of oxidation of the iron sulphide than heating in dry or even moist air. He also finds that many coals contain sulphur in the form of unsaturated organic compounds. He finds that those coals which rapidly absorb bromine are those

* "Proc. Ger. Gas Association," 1900.
† "The Gas World," April 13, 1901.

which are most liable to rapid oxidation and spontaneous ignition, and as a practical test he recommends shaking a gram of the finely-ground coal with 20 cc. of a half normal solution of bromine for five minutes. Then if the smell of bromine has not disappeared, the coal may safely be put in store; if the odor has gone, the coal should be used up as soon as possible. If the oxygen is absorbed by the unsaturated organic compounds, the coal gains weight, but if absorbed by the carbon and hydrogen, this absorption causes a loss in weight due to the carbon-dioxide and water given off. Whether a coal gains weight is, therefore, dependent upon the composition of the coal. Covering wet slack coal with other coal is apt to produce spontaneous ignition; the danger here appears to arise from the sulphide of iron rather than from the organic compounds. Professor Fischer regards ventilation of the coal heap with suspicion, not because the idea is in itself wrong, but because it is not practicable to ventilate the whole heap sufficiently. He says the coal should be stored dry and kept dry under cover and in layers not too deep.

Durand, 1863*, explains the spontaneous ignition of coal in the pit by the presence of pyrites, which, becoming heated, gives rise to combustion. Payol maintains that the main cause of spontaneous ignition is the absorption of oxygen accelerated by fine division and heat.

Jackson, 1905 †, says it is well known that coal on exposure to the weather does lose some of its volatile constituents even under ordinary conditions.

In a paper read before the German Gas Association in 1900‡, Herr Sohren said that it is no longer possible, for many reasons, to operate gas works with a supply of coal renewed from month to month; and that all questions affecting storage have, therefore, a continuously increasing importance. Undoubtedly there is a greater or less depreciation in quality of

* "Journal American Chemical Society," Dec., 1900, and July, 1904.

† "Engineering and Mining Journal," July 14, 1906.

‡ "Gas World," April 13, 1901.

coal kept in store; and the causes of this have attracted a great deal of attention, though, on the whole, it is surprising to find to how great an extent the study of the chemistry of coal has been neglected. Questions of this nature first assumed importance in connection with the spontaneous ignition of coal in ships; in 1874 he declares that out of a list of 4,485 coal-laden ships, no fewer than 60 went on fire.

Lieutenant Commander J. R. Edwards, of the United States Navy, 1901*, said that experience has taught the dealers at Trinity Building, New York, that every time coal is handled there is a depreciation of five per cent. in value due to the loss in weight by the breaking up of the coal and the volatilization of the hydrocarbons. It is a fact that the best coal does not disintegrate and powder so quickly as the poorer quality. According to his theory, the hydrocarbons make it less friable.

Groves and Thorp† state that gases occluded in the crevices or cavities of coal escape during mining and continue to do so after storing, and that disastrous explosions on vessels carrying coal cargoes have resulted. An analysis of these exuded gases reveals their inflammable nature and suggests the probable action of the air on coal which is exposed to it for any length of time. This latter action is termed "weathering," and consists mainly in the combination of the carbon and hydrogen of the coal with the oxygen of the air, carbonic acid and water resulting. Pyrites, if present, is also oxidized, and when present in large quantities causes the coal to disintegrate and oftentimes to be nearly useless. Calorific value is diminished by this exposure to the air, and in some cases there is claimed to be 50 per cent. loss. Oxidation may proceed so far that elevation in temperature occurs and spontaneous combustion results. Oxidation of pyrites, especially in the presence of moisture, greatly adds to the danger. To avoid the small coal, the packing of coal in lumps in vessels is proposed, but the movement of the ship would break up the coal and only

* "American Society of Naval Engineers," Feb., 1901.
† "Chemical Technology," Vol. 1, page 82-83.

delay the action. Sealing up the coal hermetically has also been suggested, but this would be impossible.

T. Rowan suggests the heating of coal to drive off the moisture before storing on board. The plan is a poor one on account of the cost and the oxidation which the heating would promote.

A. D. Parker, General Auditor, Colorado Southern Railroad, 1902*, states that the loss in transporting coal has never been definitely determined. It consists of shrinkage, droppings, stealing, etc. Evaporation or shrinkage is inevitable. It is greater with softer coals and diminishes with density. Where coal is placed in storage, shrinkage becomes a very large item.

Mr. Stelkins, in his report before the International Navigation Congress, 1902†, states that the tendency towards spontaneous ignition increases with the height to which coals are heaped. Stacks should not be made higher than five meters. Warm rains during and after stacking and strong compression by dumping coals from a great height all add to the danger of ignition. According to past experiences, gas-flaming pit-mouth coals ignite most readily, fat pit-mouth slack, lean slack and nut less readily, and lump coals only very seldom. When the amount of slack increases, and the amount of stony material increases, the height to which it is safe to store coal decreases. Mr. Zorner, in this same convention, claimed that lightering coal renders it more liable to physical and chemical attacks and more difficult to use as fuel. Rischowske ascertained a loss of three per cent. in calorific power of fresh slack coal after a storage of four months.

"Engineering News," July 21, 1904, notes that in the New York Navy Yard space is not an item, but spontaneous combustion is an important one, hence the coal depth is limited to 18 to 25 feet, and the walls surrounding the bins are fireproof. In each bin which contains 525 tons of coal are placed two four-inch pipes, each containing thermostats elec-

* "Railway Engineering News," May 3, 1902.

† "American Society of Naval Engineers," Feb., 1901.

trically connected to an annunciator. These thermostats containing tubes are arranged so as to be moved completely through the coal. A method of removing coal from the bottom of the bins is provided, and this may be done and the portion removed and redistributed over the top to prevent fire.

F. M. Griswold, of the Home Insurance Company, 1904*, says that spontaneous ignition is more marked in free-burning or so-called "high-steaming coals" including "gas coal." These coals usually contain a large per cent. of volatile constituents with a modicum of oxygen, and the tendency to ignition is greater when lignite or sulphur in any form, and especially when iron pyrites is present. Dirty or mine-run coals, wherein fine particles sift to the bottom and are compressed, are dangerous. He claims that no satisfactory explanation of spontaneous ignition of bituminous coal has been made. The best authorities say it is due to chemical changes in the substance of the coal resulting from the absorptive powers of carbon increasing with the rise of temperature. Rise in temperature may be due to the chemical action in the form of the slow oxidation or to mechanical force or pressure and these conditions may be stimulated by pyrite or moisture. Some claim that over 2½ per cent. of sulphur in the form of pyrites is dangerous. Various tests have been proposed to determine the liability of a coal to heat, such as determining the gain in weight of a sample at 250 degrees Fahrenheit and also by noting the absorption of bromine, but these are not valuable, as it is difficult to tell how much oxygen the coal has already absorbed. He recommends that no wood be used in the construction of bins, that all iron work be covered with concrete, that there should be no steam pipes or flues in bins, the coal should not be above a depth of twelve feet, bins should be roofed, permanent pipes should be provided, if possible, containing thermostats through the bin, and when 140 degrees Fahrenheit is reached something should be done to stop rise in temperature.

Professor Vivian B. Lewis, Royal Naval College, 1906†,

* "Engineering News" 27, 1902, July 21, 1904, Aug. 18, 1904, and Nov. 10, 1904.

† "Engineering and Mining Journal," July 14, 1906.

is authority for saying that increase of mass leads to spontaneous combustion. Substances, especially those of vegetable origin, undergo slow oxidation at temperatures below ignition point. A certain increment of temperature is generally needed to start slow combustion, but when once the required rise takes place, the operation commences and the ignition point is reached. Initial increase may be brought about in several ways: first, by physical action, as in the absorption of a large volume of gas and its compression within the pores of the substance; second, by a rise in atmospheric temperature; third, by a direct chemical reaction taking place at ordinary temperature and by the action of ferments on moist organic matter. To the first class belongs the spontaneous ignition of a mass of powdered charcoal or lamp black. Coal may be considered as consisting of carbon, hydro-carbons and inorganic constituents. Among the latter is iron pyrites. If piled in heaps and exposed to air and moisture, it rapidly heats and often inflames, owing to the oxidizing action of the air and moisture upon the sulphur. Many think this is the cause of spontaneous ignition. Careful study of phenomena occurring during the heating of coal leads to the conviction that pyrites plays but a subsidiary part, and that it is really the absorption of oxygen by the freshly-won coal and the activity of the condensed gas in contact with the hydrocarbons of the coal that are the active factors in causing ignition. In the coal seam coal pores are filled with methane or methane and carbon dioxide. When coal is brought to the surface it exudes these gases and absorbs oxygen from the air. As long as the pieces are fairly large no heat is perceptible, but as coal becomes broken up the surface increases and the absorption of oxygen is increased. Mere absorption of oxygen is insufficient to bring about serious consequences unless there is an initial rise in temperature. Hence, spontaneous ignition is found to occur when cargoes go through the tropics and when coal is stored close to boilers, steam pipes, fire boxes, etc. Water aids the action of the occluded oxygen, and hence rain, when coal is being loaded, causes danger. Ventilation of

coal on land may aid in preventing ignition, but this is hard to obtain on shipboard. Steam and water have failed to quench fires successfully. Sulphur dioxide and carbon dioxide will extinguish the fires, but not cool the coal and prevent another fire. He suggests that liquid carbon dioxide be placed in vessels whose nozzles are made of an alloy of lead, tin, bismuth and cadmium melting at 93 degrees centigrade and that these vessels be placed in the coal bins. When the melting point of the alloy is reached the carbon dioxide will quench the fire, cool the coal, be absorbed by the coal and prevent any further occlusion of oxygen.

A. E. Dixon, 1906*, says that bituminous and semi-bituminous coals are losing constantly in heating value. Gas is being liberated and the loss is greater in a warm climate and in warm weather. Bituminous coals undergo a slacking process, the lumps shrink and the percentage of dust increases. In winter the contained moisture freezes and breaks up lump coal. Spontaneous ignition occurs with bituminous, friable coal, and particularly with those grades containing brasses or iron pyrites, and when the coal is damp the trouble is augmented. The cause is probably due to the absorption of oxygen by carbonaceous material, just as is the case with oily cotton waste.

H. R. King, 1905†, claims that the carefully-executed tests in Europe show that 30 per cent. of the fuel value of coal is lost in six weeks when coal is stored out of doors.

The Naval and Military Record of England‡ gives an instance of where the British ship *Spartiate* required 3,000 tons of coal stored in England in running to China and 4,400 tons of practically the same grade of coal that had been stored in China for the return trip.

Lord Charles Beresford, 1903§, stated that in his experience a vessel would have to consume more than twice the normal amount of coal per indicated horsepower if the coal had been kept too long in store.

* "Engineering Magazine," September, 1906.
† "Journal Western Society of Eng.," Aug., 1906.
‡ "Engineer," July 24, 1903.
§ "Practical Engineer," Oct. 2, 1903.

Churchyard, locomotive engineer of the Great Western Railway, England, 1902*, stated that judging from his personal experience and observation, the loss of stacked coal in steam-raising power is about 10 per cent.

"Mines and Minerals," 1901†, says that for many years there has been in vogue in New South Wales a custom of taking certain percentages from the gross weight of coal cargoes, giving bills for the net quantity only. The idea was to allow for the wastage which it was thought took place in various ways between the time of weighing at port and delivery. The practice has been to deduct two per cent. from the gross weight of foreign exportations and one per cent. from that intended for intercolonial markets. On account of the dissatisfaction with this method, on January 1, 1901, the deduction on foreign cargoes was reduced to one per cent. and no allowance is now made on intercolonial cargoes.

The "Journal of the Society of Chemical Industry," 1894‡, says that various kinds of coal were exposed freely to the air, immersed for twelve months in water, both running and stagnant, and changes produced in their composition and heat of combustion determined. The three kinds of coal used were, (1) from Frankenholz mine, Bavaria; (2) from Drocourt; (3) from Arsean, Prele. These coals were broken and passed through 10 mm. mesh, but not 3 mm. mesh. Measurements show that exposure to the air or immersion in water for the time indicated produces changes in the composition and heat of combustion which are so small as to be neglected for practical purposes.

John Macaulay, General Manager of the Alexandra Docks and Railway, Newport, Monmouthshire, 1903*, estimates that in case of coal stacked by the Mersey Railway the loss was between 10 and 12 per cent., and, if kept over a year, the greatest loss is in the first twelve months. In hot climates the loss is greater. Mr. Macaulay says that the mud men

*"Practical Engineer," Oct. 2, 1903.

†"Mines and Minerals," 1901, p. 6.

‡"Jour. Soc. Chem. Ind.," 1894, p. 1182.

along the Usk River gathered parts of submerged cargoes and found that the coal gave a hotter fire than did fresh coal. In North Pembrokeshire they refloated a vessel which had been sunken for two years and found that the coal was the best they had ever used. Mr. Macaulay's own experiments include the placing of a sample of the best Monmouthshire coal under sea water for two months and comparing the calorific value before and after immersion. He found the loss in heating value was less than one per cent. In his further experiments he made a practical test of fresh coal and coals known to have been submerged various lengthy periods of time, by using them in a locomotive hauling a known load a certain distance under similar conditions. His first sample was the best Monmouthshire coal procurable, the second sample had been under water three years, the third had been submerged ten years, the fourth had been recovered by mud men outside of the mouth of the River Usk. This latter was driftage from the wrecks in the Bristol Channel, and had probably been under water considerably longer than ten years; this sample he called "river coal." The order of value in steam-raising and actual working results, in which the coals came out in tests, was: (1) the river coal; (2) coal that had been under water ten years; (3) fresh coal; (4) coal that had been under water three years. Comparing values with the fresh or test coal, the river coal was 4 per cent. better, and that which had been under water ten years 1.8 per cent. better. That which had been under water three years had lost 1.6 per cent. of working power. The high value of the older river coal. he says, may probably be accounted for by the fact that in traveling through the mud and sand that gave it its rounded form the harder and better kernels, as it were, had been preserved, and the looser-textured, less valuable outside portions were worn away. As a result of his experiments Mr. Macaulay concludes that steam coal loses very little of its power by submersion under water for the length of time that it would reasonably be kept in naval store, and that as it is so important to naval vessels to gain the benefit

of their full working power, and so much of this is due to the coal, the subaqueous storage of coal is advisable in place of the present methods of storing with access to air, by which so high a percentage of working power is lost.

SUMMATION OF OPINIONS.

Judging from these opinions of practical engineers and scientists, the present methods of coal storage without doubt often result in much loss from fires of spontaneous origin and more or less loss by a deterioration in fuel value of the coal itself. The leading factors entering into the cause of these losses have been pointed out as being: (1) the kind of coal as to its volatile combustible content; (2) the presence of occluded inflammable gases in the coal both before and after mining; (3) the presence of pyrites or other sulphur compounds; (4) the size of the coal; (5) the presence of moisture; (6) the temperature; and (7) the accessibility of oxygen to the coal.

From the evidence at hand there seems to be very little doubt that the coals of the lignitic, bituminous and semi-bituminous character with their relatively high amounts of volatile combustible matter have a much greater tendency to weather than the anthracites where the volatile matter is low. There is considerable evidence that methane and other inflammable gases formed during the decomposition of vegetable matter which produces the coal are contained in the crevices of the coal as it lies in the earth, and are liberated both during and after mining. This exudation of inflammable gaseous matter may be a prime element in mine explosions, and its continuance after storage may be a large factor in the deterioration processes.

Opinions differ as to just what part sulphur compounds, the most important of which is pyrites, play in the deterioration of coal. Some assign the leading part in cases of spontaneous ignition to pyrites, while others think that its action in this connection is of only minor importance, and that absorbed oxygen has most to do with this phenomenon. Observations on

the effect of the air upon pyrites, however, seem to have pretty generally established the notion that pyritic oxidation tends to raise the temperature of the coal as well as to increase the tendency of the coal to break up, and that this oxidizing action is quite appreciably increased by the presence of moisture.

That slack is much more liable to spontaneous ignition and the deteriorating influence of weathering agents seems to be the general opinion. Having more surface the finer particles absorb oxygen much more rapidly, and this rapidity of absorption causes an increase in temperature which in turn produces better conditions for absorption and chemical action between the carbon, hydrogen and pyrites of the coal and the absorbed oxygen. It would seem that the finer coal would hold the moisture longer, resulting in a greater use being made of its catalytic qualities.

It is thought by some authorities that the only part moisture plays in the deterioration of coal is to materially assist the pyritic oxidation, or by alternate freezing and thawing in the crevices of the coal to expose more surface to weathering agents. There are many, however, who believe that, aside from increasing the oxidation of pyrites, water has to do with other chemical activities which result in the decomposition of the coal. These believe that oxidation of the carbon and hydrogen of the coal is hastened by the action of the water present. This latter view seems to be based on the fact that moisture has seemingly, in some instances, greatly increased the deterioration of practically non-pyritic coal.

That an increase of temperature has much to do with increasing the activity of the other deteriorating agents is the general belief. This rise of temperature, whether coming from outside sources or physical or chemical action within the coal, tends to accelerate the absorption of oxygen and thereby increases the oxidation going on and also evaporates the gases which may still be occluded in the coal. Thus heat assists in decreasing the fuel value of the coal and at the same time increases its liability to ignition. That the exclusion of oxygen

from coal will decrease its loss in heating value is a growing belief.

From the evidence at hand, therefore, it would seem that not only do observers differ widely as to the causes and extent of weathering, but no very exact study of the problem has been made in all of its phases on which could be based very much either of theory or fact concerning the deterioration of coal in storage.

Any discussion of the matter from our own standpoint will be reserved until after presenting the results of our experiments as outlined in the following pages.

EXPERIMENTAL WORK.

It seems necessary to concede at the outset that coals will differ as to the extent of their deterioration, because of their individual peculiarities of either a chemical or physical nature. It should be said at the outset, therefore, that in the present studies no attempt has been made to include all types of bituminous coals, but only those of the Illinois field. In this series an effort has been made to cover a number of localities furnishing a fair representation of the different coals of the State. Briefly outlined the conditions under which the coals were studied were as follows. The starting point was the coal in its normal state, that is, as nearly as possible corresponding to the condition existing when broken out of the vein. The period of time between the mining of the coal and the initial analysis varied somewhat, but the first series of tests was made as soon as possible after the coal was mined. In the light of subsequent developments greater stress should be put on the early examination of samples to determine the initial condition. Even under the most careful disposition of samples in laboratory containers, a deterioration takes place which, while not exactly a "weathering" process, is still a large element in any study of the case and must be considered if exact conclusions are to be available.

There were nine initial samples taken of approximately 100 pounds respectively. The coal was of small lump or nut size,

and each sample was subdivided in order to subject the same kind of coal to various conditions. These conditions were to be continued through nine months, and in general were:

(a) Outdoor exposure.

(b) Exposure to a dry atmosphere at a somewhat elevated temperature ranging between 85 degrees and 120 degrees Fahrenheit.

(c) Under the same conditions as (b) so far as temperature was concerned, but to be drenched with water two or three times per week.

(d) Submerged in ordinary water at a temperature approximately 70 degrees.

The periods for examination were divided as nearly as the work would permit into

1. The initial analysis of the fresh coal.
2. After exposure for five months.
3. After exposure for seven months.
4. After exposure for nine months.

For the sake of comparison also the calorific values were determined under uniform conditions throughout by means of the Parr calorimeter and the results calculated to the ash and water free basis to eliminate any variations in the process of sampling and to make, as far as possible, the different samples as well as the different lots comparable among themselves.

Concerning the results it should be noted that while experiments are of a preliminary nature, largely devised to gain information for carrying out more elaborate and comprehensive tests, they are sufficiently consistent among themselves to justify certain tentative propositions, as follows. There is evidence, first of all, of a distinct difference between the submerged coal and that which was exposed to the air. The values found for the submerged coal throughout the nine months did not vary, with possibly one or two exceptions, by greater amounts than would occur in tests made on succeeding days by the same operator. Values obtained so far apart as to time, with the inevitable modifications due to tempera-

ture, atmospheric conditions, etc., may fairly be considered as checking if they agree within 100 or 150 units. There may indeed seem to be a uniform tendency to fall slightly in values, but from the showing the submerged coal may very fairly be said to remain constant.

If we consider next the outdoor exposure, it should be said that these samples were contained in shallow boxes placed on the nearly flat roof of a building and subjected to the changes of temperature and moisture common to the months from October to July. The coals varied somewhat in their tendency to crumble, but all showed more or less of the "slaking" process. The remarkable fact in this series is the wide variation in the amount lost, ranging from approximately 2 to 10 per cent. The question naturally arises as to whether this a natural characteristic of the different coals or whether the same variations would be found under different conditions, as, for example, the storing in large masses instead of the small lots worked with. Attention should also be called to the fact that during the progress of this work, as will be shown under another topic, proof was obtained of the positive loss of values in samples stored under supposedly the best laboratory conditions. The rate of progress of this loss has not been determined, though it is presumably slow. The effort was made to obtain the initial values on all the samples to be subjected to weathering at the earliest possible date after being mined, but variations as to time were inevitable, and the importance of guarding this point was not so fully appreciated at the outset as it was at the close of the work.

In further studies along this line this particular element in the case will be guarded with due care, but there is no evidence so far that the results would be materially affected or would be different from the general indication of the charts.

Not the least striking of all the results are those obtained from coal stored in a thoroughly dry atmosphere. The fact that these samples lost in the aggregate quite as seriously as those exposed to outdoor conditions, and, if anything, even to

a greater extent, would seem to indicate that moisture has little to do with the processes of deterioration. It must be conceded, of course, that, so far as relates to the weathering out of pyritic sulphur, moisture is an essential condition, but the losses are so much greater than would be represented by the leaching out of sulphur that this element is practically obliterated as a factor in the results. If anything is proved indeed concerning the effect of moisture, it is that it retards rather than accelerates the loss of heat.

Other facts than these just cited substantiate the above feature of the case, tending to show that, after all, weathering is not a leaching process, or one which primarily results from the direct action of water and attendant weather conditions, but seems to be a direct loss of volatile hydrocarbons. To how great an extent there is a reabsorption of atmospheric gases and to what extent oxidation accompanies such absorption cannot be stated from this series of experiments. That water indirectly is a factor cannot be doubted, for anything which promotes disintegration facilities the escape of combustible gases. Disintegration results from handling, from freezing and thawing, and from the decomposition of pyrites. In general, we would expect greater persistency of values in the dense and less friable coals and in those with less of iron pyrites throughout their texture. In submerged coal the decomposition of the pyrites is checked and without special reference to fineness of division. The loss of volatile matter seems also to cease. These processes, which are active in the air and cease under water where the element of pressure or lack of it can hardly be a factor, suggest the idea of displacement of hydrocarbon gases by oxygen, by some process akin to osmosis or catalysis, whereby a certain amount of oxidation of the carbon or hydrogen occurs. Altogether, the results are of value, not only as touching the facts relating to the storage of coal, but especially as to their suggestions for further studies looking to fuller information of practical value on this very important topic.

SUMMARY.

(a) Submerged coal does not lose appreciably in heat value.

(b) Outdoor exposure results in a loss of heating value varying from 2 to 10 per cent.

(c) Dry storage has no advantage over storage in the open except with high sulphur coals, where the disintegrating effect of sulphur in the process of oxidation facilitates the escape of hydrocarbons or the oxidation of the same.

(d) In most cases the losses in storage appear to be practically complete at the end of five months. From the seventh to the ninth month the loss is inappreciable.

(e) The results obtained in small samples are to be considered as an index of the changes affecting large masses in kind rather than in degree, but since the losses here shown are not beyond what seems to conform in a general way to the experience of users of coal from large storage heaps, it may not be without value as an indication of weathering effects in actual practice.

THE DETERIORATION OF COAL SAMPLES.

Closely related to the weathering of coals is the subject of the deterioration of samples in storage. It would be assumed as a general proposition that carefully-sealed samples, kept at normal temperature, in glass retainers, would remain constant as to their composition. Many facts have accumulated which seem to disprove this proposition. In an article by one of the writers* reference is made to the necessity of making calorific determinations, where comparisons between different instruments are involved, at approximately the same date. To quote from that article: "A comparison of calorimeters should be made at approximately the same time. A series of calorific determinations made on finely-ground samples on May 12, 1900, was found to give a reading 2.4 per cent. less on July 12, 1900. It was necessary to repeat practically all of the above determinations on this account, all of the results

* A New Coal Calorimeter, by S. W. Parr, "Jour. Am. Chem. Soc.," Oct., 1900, p. 650.

showing a deterioration in the finely-ground samples. This subject will receive further attention later."

In correspondence and conference with other workers this fact has been questioned, as, for example, Dr. Bunte, of the Karlsrhue Polyteknikum, says that coal samples kept for analytical purposes, and which are determined by students year after year, give evidence of a constancy as to their calorific values. However this may be, the coals of the Mississippi Valley, being of a different type from the German coals, may not necessarily follow the same behavior in storage. Indeed, it may be doubted if the coals of Western Pennsylvania and Virginia would show the same behavior in this respect as the coals of the Mississippi Valley. At any rate, there have accumulated a number of facts which point to the deterioration of Illinois coal samples in laboratory storage, and it is the purpose of this paper to give the evidence which has come to hand up to the present time.

The matter is of importance, not only from its bearing upon an understanding of the matter of the weathering of coals, but in connection with all matters pertaining to the comparison of values as between different samples. It is to be taken into account also in considering the value which is to be placed upon the "pure coal" idea as frequently set forth, to the effect that the ash and water free basis is common ground for comparison under all conditions. It is exceedingly helpful and, indeed, essential, in the scientific study of coals, to have a unit of reference which may be used as a basis of comparison, but it is essential also to know the variations which may enter into such a unit, in order to avoid errors in the ultimate conclusions.

In comparing the values of Illinois coals, as obtained by the United States fuel-testing plant at St. Louis, with the values determined in this laboratory by the Illinois State Geological Survey on coals from the same districts, it was found that considerable discrepancy existed upon referring the results in both cases to unit basis, as, for example, the ash and water free condition. Perhaps the most striking fact

in this connection was the uniformly lower calorific values obtained by the State Geological Survey. The possibility of this difference being due to variations in methods and to different operators was duly considered. However, the method of sampling at the mine was the same, the sample being taken from the face of the vein, reduced by quartering in the usual manner to about two pounds in weight, sealed in tins with screw cap and insulating tape, exactly as followed by the fuel-testing plant at St. Louis.* The type of calorimeter was also duplicated, the instrument in this laboratory used in this comparison being of the Mahler-Atwater type with platinum lining and operated in a room under temperature control. A careful standardization of the instrument and a redetermination of its water equivalent were also made. The results here were so uniformly lower than those obtained at St. Louis as to call for a special study to ascertain the cause. An examination of the accompanying table will make evident the difference in calorific values as above described.

It is not a sufficient explanation to say that the samples in the two cases were not identical. Indeed, frequently they were not taken from the same mine. It is a well established fact, however, that samples taken from the same locality, when referred to a unit basis, as the ash and water free conditions, will show relatively small variations, at least within a limited area. It is true that variations in the same region do occur often; evidence of these variations is largely dependent upon the accuracy of the unit adopted for reference, and, when properly compared, these variations are not of sufficient size nor of sufficient uniformity to explain either the magnitude or the constancy in direction of the differences shown in the accompanying table. Concerning the unit of reference, it should be said that the ash, moisture and pyrite-free basis is used as approaching the nearest possible to the actual material under consideration, thereby eliminating such variables as would obviously result if no notice were taken of the presence or absence of sulphur. The weight of ash, therefore, is

* U. S. Geol. Surv. Coal-Testing Plant, Bul. 261, p. 20.

corrected by adding $\frac{5}{8}$ of the weight of sulphur present, as representing the original pyritic condition.

In taking up the study of the conditions under which the work was carried on in the two laboratories, so far as can be determined, the only point of divergence seemed to reside in the time elapsing between the date of sampling at the mine and the date at which the determinations were made in the laboratory. In the case of the fuel-testing plant at St. Louis this difference in time was relatively short, being presumably, as a rule, not more than two or three weeks. In the case of the State Geological Survey, because of certain exigencies, an unavoidable delay occurred, hence the time elapsing varied from six months to a year.

Two methods of caring for the samples were followed. First, where time permitted, the coal as received in the tins was at once emptied into shallow pans and the amount of moisture lost upon air drying was determined by allowing the pans to stand exposed to the air over night. The sample was then reduced to buckwheat size, one-half was sealed in glass jars of the so-called Lightning or Putnam pattern and the other half was ground in the Ball mill with porcelain jars of the Abbe type. This part of the sample was also sealed in a similar jar and set aside for the analytical work later. The analyses used in Table I for comparison with the St. Louis results were made on these finely-ground portions.

The other method of caring for the samples consisted in simply transferring the coal as received in the tins to glass containers without air drying. Fifty samples were thus disposed of, about half being stored in the Putnam jars and half in jars of the common Mason type.

As already noted, it has been impossible in this table of comparisons to select cases where the samples were exact duplicates from the same mine in each instance, but it may fairly be claimed that the uniformity with which the lower values are indicated for the older samples precludes the possibility of ascribing the difference to the character of the coal. The

TABLE 1.—COMPARISON OF NEW AND OLD SAMPLES OF ILLINOIS COALS IN LABORATORY STORAGE.

Sample numbers.	Locality.	Mine sample U. S. G. S.—Ash, moisture and pyrite free.	Mine sample, Ill. G. S.—Ash, moisture and pyrite free.	Difference.	Per cent. of variation.
U. S. G. S., Ill. No. 1	O'Fallon	14,567	...	...	...
Ill. Geol. Surv. No. 95	O'Fallon *a*	...	14,084	483	-3.31
U. S. G. S., Ill. No. 3	Marion	14,561	...	...	...
Ill. Geol. Surv. No. 330	Marion *a*	...	14,335	226	-1.55
U. S. G. S., Ill. No. 9	Staunton	14,615	...	...	...
Ill. Geol. Surv. No. 94	Staunton *a*	...	13,923	692	-4.72
U. S. G. S., Ill. No. 10	W. Frankfort	14,647	...	...	...
Ill. Geol. Surv. No. 364	W. Frankfort *b*	...	14,332	315	-2.15
U. S. G. S., Ill. No. 11	Carterville	14,731	...	...	...
Ill. Geol. Surv. No. 325	Carterville *a*	...	14,213	518	-2.15
U. S. G. S., Ill. No. 15	Centralia	14,587	...	...	...
Ill. Geol. Surv. No. 167	Centralia *b*	...	14,200	387	-2.65
Ill. Geol. Surv. No. 169	Centralia *a*	...	14,376	211	-1.44
U. S. G. S., Ill. No. 16	Herron	14,558	...	...	...
Ill. Geol. Surv. No. 323	Herron *a*	...	14,321	237	-1.62
U. S. G. S., Ill. No. 18	LaSalle	..	14,722	...	...
Ill. Geol. Surv. No 393	LaSalle *b*	14,440	...	282	-1.91

(*a*) Not same mine. (*b*) Same mine.

same thing may also be said with reference to variations in results which may be expected from different operators. If this were the reason for the discrepancy, one would hardly expect the uniformity as to direction of the results here indicated in the tables. To determine whether deterioration might result from the finely-ground state of the samples, the reserve sample in the coarse condition in a number of cases was taken and calorific determinations made as upon the fine samples. These results were found practically to duplicate those obtained upon the ground samples. Hence, it was concluded that if deterioration were the explanation, it had affected both the coarse and fine samples alike. It was then

decided to obtain new samples from the same localities and so far as possible from the same mines, collecting and preparing the samples in exactly the same way as before. The determinations on these samples were made within a period not to exceed ten days from the date of collection. The results, ar-

TABLE 2.—COMPARISON OF COAL SAMPLES FOR VARYING LENGTHS OF TIME IN LABORATORY STORAGE.

Lab. No. Ill. State Geol. Survey.	Source of sample.	Time of storage.	B. t. u. of ash, moisture and pyrite free.	Loss in B. t. u.	Percentage of loss.
421	Majestic Mine, Duquoin, Ill., April 17, 1907	10 days	14,386	...	...
307	Paradise Coal & Coke Co., Duquoin, Ill.	1 year	14,116	207	-1.9
459	Big Muddy C. & I., No. 7, April 18, 1907	10 days	14,615	...	...
323	Squirrel Ridge Mine, Herrin, Ill.	1 year	14,321	294	-2.0
460	Big Muddy Coal Co., No. 8, Clifford, April 18, 1907	10 days	14,615	...	...
325	Clifford, Carterville	1 year	14,213	402	-2.7
462	Peabody Coal Mine, No. 3, three miles west of Marion, Ill., April 18, 1907	10 days	14,781	...	...
330	Peabody Coal Co., Marion, Ill.	1 year	14,335	446	-2.6
540	Sangamon Mine, Springfield	1 week	14,567	...	...
82	Sangamon Mine, Springfield	7 months	14,100	467	-3.2
81	Sangamon Mine, Springfield	7 months	13,940	841	-4.3
557	Kelly No. 4, now Dearing No. 44	5 days	14,450	...	...
332	Kelly Coal Co., Westfield, Ill.	1 year	14,054	396	-2.8
558	Kelly Coal Co., Himrod Mine, Himrod, Ill.	5 days	14,564	...	...
333	Himrod Mine, Himrod, Ill.	1 year	14,087	477	-3.3

ranged for comparison with the old samples, are shown in Table 2. The striking uniformity with Table 1 is to be noted in that practically the same difference in values is shown between the new samples and the old as exists between the St. Louis results, presumably also on fresh samples, and our own results known to be on samples of from six months' to a year's standing.

TABLE 3.—COMPARISON OF ILLINOIS COAL SAMPLES WITH RELATIVELY SHORT PERIOD IN LABORATORY STORAGE.

Sample numbers.	Locality.	Mine sample U. S. G. S.—Ash, moisture and pyrite free.	Mine sample Ill. Geol. Surv.—Ash, moisture and pyrite free.	Difference.	Per cent. of variation.
U. S. G. S. Ill. No. 3	Marion	14,561	...	...	...
Ill. Geol. Surv. No. 462	Marion *a*	...	14,781	220	+1.51
U. S. G. S. Ill. No. 7	Collinsville	14,373	...	...	...
Ill. Geol. Surv. No. 725	Collinsville *b*	...	14,659	286	+1.98
Ill. Geol. Surv. No. 723	Collinsville *a*	...	14,640	267	+1.85
Ill. Geol. Surv. No. 724	Collinsville *a*	...	14,564	191	+1.32
U. S. G. S. Ill. No. 9	Stanton	14,615	...	...	...
Ill. Geol. Surv. No. 737	Stanton *a*	...	14,301	314	−2.14
U. S. G. S. Ill. No. 11	Carterville	14,731	...	...	...
Ill. Geol. Surv. No. 460	Carterville *b*	...	14,615	116	−.787
U. S. G. S. Ill. No. 14	E. Springfield	14,464	...	...	...
Ill. Geol. Surv. No. 540	E. Springfield *a*	...	14,567	103	+.711
Ill. Geol. Surv. No. 740	E. Springfield *a*	...	14,408	56	−.387
Ill. Geol. Surv. No. 741	E. Springfield *a*	...	14,429	35	−.243
U. S. G. S. Ill. No. 16	Herron	14,558	...	...	+.391
Ill. Geol. Surv. No. 459	Herron *b*	...	14,615	57	
U. S. G. S. Ill. No. 19	Ziegler	14,601	...	...	...
Ill. Geol. Surv. No. 419	Ziegler *b*	...	14,480	121	−.829
Ill. Geol. Surv. No. 420	Ziegler *b*	...	14,445	156	−1.06

a Not same mine. *b* Same mine.

Still a third series of results has been arranged in Table 3. Here the comparison is made between the St. Louis values and our own, obtained on relatively fresh samples from the

same or near-by mines. There is further confirmation of the proposition here in that the results on our own samples are sometimes higher and sometimes lower than the St. Louis values. The relative dates are not at hand in each case to indicate whether or not the plus and minus values conform to a greater or less transpiration of time before analysis, but it is worthy of noting that the discrepancies are not so wide as in Tables 1 and 2, where a positive and wide variation of time existed. Even in the third sample from Stanton (Table 3), where a difference of 2.14 per cent. is indicated, in Table 1, for the same mine, a difference of 4.72 per cent. is given.

It is now in order to refer to certain other facts which still further confirm the proposition in hand. The fifty samples above referred to as having been transferred without air drying to glass containers upon their arrival at the laboratory, were examined after about ten months' standing. Twenty-nine of the samples had been placed in the type of jar known as the Lightning or Putnam jar. Extended experience with this jar as a container for sodium peroxide, a chemical with unusual avidity for moisture from the atmosphere, has proved it to be possessed of an absolute seal. The remaining twenty-one samples had been placed in the common Mason fruit jar with metal screw cap and very indifferent seal. After the ten months of storage, upon opening the Lightning jars a slight pressure of gas was noted which suggested the testing of the same with a lighted match. In twenty-six of these jars the gas ignited with a strong blue flame, burning up from one-half to six inches above the top of the jar. Upon covering with the cap and testing again with a match, these jars would reignite for two or three successive times. Two of the jars had been previously opened without attention to the contents and it is not known whether they contained inflammable gas or not. In one other of these jars the gas was carbon dioxide, judging from the fact that instead of igniting the match was extinguished. Not one of the Mason jars with the zinc cover contained any pressure of gas and no tendency to ignite was manifested. It should be

noted that all of these jars were in diffused light, but not in direct sunlight, and that only the Lightning jars possessed perfect seal. We have herein evidence of the tendency of the coal to give off combustible gas after being broken out of the vein, and if we accept the theory proposed by Richter and others, that this exudation of combustible gas is accompanied by a corresponding absorption of oxygen from the air, we may readily understand some of the processes which go on in the deterioration of samples as well as in the weathering of coal.

One further incident is worthy of notice in this connection. Certain samples used in Coal Bulletin 2, published as the University of Illinois Studies on the Composition of Coal, 1904, were opened after three years of storage in jars of the Lightning type. These samples had not been opened during the three years. It was noted that much of the iron pyrites disseminated throughout the coal had become oxidized to ferric sulphate. This suggested that by leaching out this compound, and estimating the sulphur thus transformed to sulphate, we could calculate the amount of oxygen necessary to bring about the reaction from the form of iron pyrites, (FeS_2) to ferric sulphate, $Fe_2(SO_4)_3$. It was found that the amount of oxygen required to oxidize the weight of sulphur found was 1.99 grams, and calculated to the equivalent volume of pure oxygen would be 1.39 liters, or, if calculated to the equivalent of atmospheric air, it would require 7 liters of such air to furnish the necessary oxygen for the reaction. When it is remembered that the jars in which these samples were kept had a volume all told of only one pint and that this space was occupied at least to the extent of three-quarters of the total with coal of buckwheat size; and when we further remember that these jars were possessed of absolute seal, without opportunity for transference of oxygen from without, there is furnished evidence of the fact that occluded oxygen or absorbed air must have been present in sufficient amount to accomplish the work indicated by the transformation of the pyrites to ferric sulphate.

It would seem from the above experiences that there is not

only sufficient evidence to establish the fact of the deterioration of coal samples, but a fairly well established explanation as to how this deterioration takes place. Other tests along this same line are being carried out from still other standpoints, and, while they are not complete, the evidence is all in the same direction as that adduced above.

SUMMARY.

(a) An exudation of combustible gases from coal occurs from the time of breaking out of the sample from the vein.

(b) An absorption of oxygen accompanies the exudation of hydrocarbons.

(c) Samples of coal in most carefully sealed containers are subject to deterioration.

(d) The process of deterioration is probably due to oxydation of hydrogen or hydrocarbons by means of the absorbed oxygen. It may also be due to a simple loss of combustible gases and the replacement of the same by non-combustible gases such as oxygen.

(e) The rapidity or extent of this deterioration varies with different coals, but is probably most active during the first two or three weeks from the taking of the sample, but does not seem to reach a normal state till after a few months have elapsed. Further data on this point especially are necessary.

It is interesting, also, to bring together the averages of the results in the three tables for further comparison. There is thus afforded further evidence suggesting the fact of deterioration.

TABLE 4.—AVERAGES FROM TABLES 1, 2 AND 3.

Illinois State Geological Survey—Eight old in comparison with eight new samples—from Table 1	Average 2.85 per cent. lower.
Illinois State Geological Survey—Nine old samples in comparison with nine results by U. S. G. S.—from Table 2	Average 2.40 per cent. lower.
Illinois State Geological Survey—Twelve fresh samples in comparison with results by U. S. G. S.—from Table 3	Average 0.20 per cent. higher.

THE FASTEST SHIPS IN THE WORLD.

At the beginning of every year it is customary to review the progress made in shipbuilding during the previous twelve months, and by picking out the salient features of each contributory line of evolution to strive to form the best idea of the directions of greatest progress or the tendencies of future development. Two facts stand out at present above all others. The first, affecting merchant steamers alone, is the enormous improvement in the comfort and luxury of ocean voyaging; the second, with which we are now concerned, is the great rise in absolute speed which, though very marked in special cases in the mercantile marine, is much more general in the warships of the world. It is, however, impossible to form any opinion of value by simply considering the progress of one particular year, and we propose to deal with the growth in speed since the beginning of the century.

It is a very simple matter—given the money—to produce a small vessel of abnormal speed. Cases such as the famous *Arrow* or the *Turbinia*, in which absolutely everything is sacrificed to pace, do not represent, by any means, the acme of naval architecture. Interesting they certainly are, but their use and value are doubtful and transitory. When, however, it becomes a question of attaining not only a very high speed, but of *maintaining* it, and of carrying weight in addition, be it cargo or coal, guns or armor, the problem becomes different and more difficult, while if, in addition to this, the vessel must be commercially profitable, the conditions become extremely hard to fulfill. The case of the recent Cunard vessels is one of the most up-to-date examples available. In warships, of course, the question of cost hardly enters, and use can be made of designs or materials that dividend-earning concerns could not afford, and in which at the same time there is neither the need nor the inclination to take the risks or reduce the margins that are accepted in naval work. The two cases must, therefore, be treated separately.

For a floating ship-shaped body propelled on the surface of

the water speed has also a relative value, the real measure being its ratio to the square root of the length, viz: $\frac{V}{\sqrt{L}}$ where V is speed in knots and L is length in feet. In cases where the value lies between 0.5 and 0.7 the ship is being driven at a very moderate and economical speed; between 0.7 and 1.0 we find the speed of mail steamers and battleships, and between 1.0 and 1.3 we get cruisers and channel steamers. Beyond 1.35 we cannot go in full-sized vessels under present conditions, because it is not possible to get enough engine and boiler power into the ships, on account of the fact that the floor space available in the ships is not sufficient; but it can be done in torpedo craft by using very high-speed engines and excessive forced draft to the boilers. In these ships the ratio of $\frac{V}{\sqrt{L}}$ is between 1.8 and 2.2, and only in very exceptional cases has the latter ratio yet been exceeded. The reason underlying the importance of this ratio is that the wave-making resistance of the ship does not increase regularly, but in humps of varying magnitude, the first of which occurs at a speed of about 1.4 to 1.6 times $\sqrt{L}$. From the above it follows that speed should always be considered relatively as well as absolutely.

WARSHIP SPEEDS.

One of the earliest and relatively fastest vessels built was the *Forban* of the French Navy, which was constructed by Normand at Havre in 1895. She attained 31.2 knots, though only 144 feet long, displacing 125 tons and requiring 3,950 I.H.P. For some years she held the record for speed, and was always a remarkable vessel, her success being almost entirely due to her exceptional machinery. The *Turbinia*, early in 1897, was the first vessel to break the *Forban's* record. Up to 1900, about eighty vessels had been built which had, on genuine official trials, attained a speed of 30 knots. Sixty of these were in the navies of England (48) and

Japan (12). They were all propelled by reciprocating engines, and for the most part averaged from 210 to 215 feet in length by 20 to 22 feet breadth. The power was about 6,500 I.H.P.

In 1900, however, the trials of H. M. S. *Viper* astonished everyone. This vessel still holds the record for speed, having attained over 37 knots when displacing 370 tons. She was of exactly the same dimensions as the 30-knotters, but with larger boilers—having 275 square feet of grate area, compared with about 220 in the other ships, the respective heating surfaces being 15,000 and 12,000 square feet. The *Viper* was the first vessel to be fitted with Parsons turbines (except the *Turbina*), and the results of her trials are given in Table I. The turbines weighed about 7½ per cent. less than the reciprocating engines of only half the power fitted in the sister ships.

TABLE I.

Trial.	Speed in knots.	Equivalent I.H.P.	R.P.M.	Coal burned per hour, pounds.	
				Total.	Per I.H.P.
Maximum power (1 hour)	37.113 max. 36.58 mean	13,000	1,180	34,500	2.61
3-hour coal consumption	33.83	10,300	1,050	25,700	2.49
3-hour official trial	31.118	8,350	950	19,800	2.38
12-hour slow speed	15.0	750	450	3,000	4.03

The *Viper* was lost by running ashore, and the *Cobra*, a very similar vessel of slightly slower speed, broke her back through structural weakness and sank in the North Sea. The loss of the *Cobra*, coupled with signs of weakness in many of the 30-knotters, resulted in a change of policy in the construction of these high-speed vessels, and structurally heavier hulls were afterwards required, the consequent sacrifice in speed being accepted. In England, therefore, between 1901 and 1905 no really fast destroyers were built for the British Navy. One exceptionally fast vessel, the *Mode*, was built by Yarrow for the Swedish government in 1902, a speed of 32.4 knots being obtained; but in other navies no attempt was made to exceed 30 knots—in fact, Germany was content with 27 knots and France and Italy with about 28. Until

this year hardly any new torpedo craft have been constructed in the United States for some years.

Towards the end of 1905, however, the British Admiralty laid down five ocean-going destroyers, most of which have just completed their trials. These vessels and the subsequent batches of two laid down in 1906 and five in 1907 are all about 250 to 280 feet long, and displace about 850 tons. The speeds attained on a six-hour trial have varied from 33.14 in the *Cossack* to 34.3 in the *Mohawk*, which latter at present holds the record for being the fastest ship afloat.* Propelled by Parsons turbines of about 17,000 horsepower, these vessels are very remarkable in many ways. They carry a poor armament (only three 12-pounders and two 18-inch torpedo tubes), but are especially built for sea keeping in company with the fleet. They carry 160 tons of oil fuel.

Another remarkable vessel, *G137*, was completed in 1907 by the Germania Company, at Kiel. Also propelled by turbines, *G137* is extremely similar to the British River-class boats of 26 knots speed that were built in 1903 and 1904. She attained a speed of 33.1 knots on her trials at 580 tons displacement, and carries no less than four torpedo tubes, one 15-pounder and four smaller guns.

The extraordinary success that attended the speed trials of all these very fast vessels of 1907 has gone a long way to assure naval architects of the success of H. M. S. *Swift*, which is by far the most remarkable ship now under construction, from the speed point of view. Built for a speed of 36 knots on an eight-hour trial under service conditions, the vessel displaces no less than 1,800 tons on 10 feet 6 inches draught. The armament will include four 4-inch guns. The ship was launched on Dec. 7, 1907.

Table II shows the leading dimensions and speeds of all these vessels, together with the dates of their trials. The years 1903, 1904, 1905 and 1906 do not show any progress of importance, 30 knots being the extreme speed attained, and

* Eclipsed by the sister boat *Tartar*, which, on December 17, averaged 35.36 knots for 6 hours, and made 1 mile at the rate of 37.037 knots.

most navies contenting themselves with slower vessels of more durable construction. The performance of *G137* is remarkable in that it was attained with coal fuel. Oil fuel seems likely to become an absolute essential in the design of these very fast craft, for it admits of several advantages which cannot be ignored :

(1) Greater calorific value, giving either greater radius of action on same weight of fuel, or less weight for same radius.

(2) Greatly reduced stokehold space required, especially in a fore-and-aft direction.

(3) Greater ease of manipulation.

It is interesting to note how the length of these vessels has increased in proportion to the speed; the ratio has remained very constant during the last seven years.

TABLE II.

Vessel.	Date.	Length, feet.	Speed, knots.	$\frac{V}{\sqrt{L}}$	Horse-power.	Displace-ment, tons.	Horse-power per ton *D*.	Admiralty coefficient.
Forban	1895	145	31.2	2.59	3,950	125	31.6	192
Turbinia	1897	100	33.0	3.3	2,200*	44.5	49.5	205
English Navy	'98-'00	210	30.0	2.07	6,500	320	20.3	194
Japanese Navy	1899	220	31.0	2.09	7,000	315	22.2	197
Viper	1900	210	37.0	2.55	13,000*	370	35.1	200
Mode	1902	220	32.4	2.175	7,500	400	18.8	246
G 137	1907	235	33.1	2.16	13,400*	580	23.1	188
Cossack†	1907	270	33.2	2.02	17,500*	830	21.1	185
Swift†	1908	345	36.0	1.94	33,000*	1,800	18.3	209

* Turbine machinery. † Oil Fuel.

TABLE III.

Vessel.	*Swift.*	*Sentinel.*	*Amethyst.*	*Encounter.*
Length, feet	345	360	360	355
Breadth, feet	35	40	40	56
Displacement	1,800	2,800	3,000	5,800
Speed, knots	36	25.5	23.6 (21 75 design)	21.0
Horsepower	33,000	17,500	14,000 (10,000 design)	12,000
Armament	4 4-inch 0 tubes	10 12-prs. 8 1¼-prs. 2 tubes	12 4-inch 8 3-prs. 2 tubes	11 6-inch 9 12-prs. 2 tubes
Protection	nil	armored deck	armored deck	armored deck
Coal at normal draught	180 tons (Oil fuel)	150 tons	300 tons	500 tons
Date	1908	1905	1904	1902
$\frac{V}{\sqrt{L}}$	1.94	1.344	1.245	1.13

In all these cases we have considered vessels of abnormal absolute speed, in which great sacrifices of armament and

protection have been made to secure pace. We shall proceed next to work back to vessels of the cruiser type, which are also relatively high-speed vessels. The first step in the connection is obviously through the *Scout* class of cruiser, and as it happens that these vessels are remarkably similar in general dimensions to the *Amethyst* type of third-class cruiser, we have compared these vessels in Table III, adding the most recent type of second-class cruiser. After this point in British naval practice there is a radical change. The size of vessels necessitates their being protected by external armor, and the necessary compromise of weights involves a reduction in machinery. We then begin to get to comparatively slow proportionate speeds. Thus, for instance, the very fast cruisers of the *Good Hope* and County classes of 500 and 440 feet in length, have speed-length ratios of only 1.075 and 1.1, respectively.—"International Marine Engineering."

THE APPLICATION OF MOTORS TO MACHINE TOOLS.*

BY DEXTER S. KIMBALL.

The introduction of electrical distribution and the electric motor gave to engineers of large plants a solution to a problem that had for a long time been very troublesome. The old method of power distribution with its wide belts and large shafts, and when the plant was large its detached engines and sometimes boilers, was quickly recognized as far inferior to the new method. By this method the great friction losses due to large shafts and belts were eliminated and centralization with its accompanying economy could be carried to its highest form. The larger the plant the greater was the advantage to be gained, so that it quickly became good practice to distribute power electrically, and run the various lines of small shafting by motors belted to them.

By an easy extension of this system the larger tools were soon belted to their own individual motors and the advantages

* Taken from the Proceedings of the combined Electrical and Mechanical Engineering Societies of Cornell University.

so gained were evident to all, and up to this point engineers were fairly well agreed. But engineers soon came forward with the claim that great economy could be obtained by attaching a motor to every tool and doing away with all belts and shafts. On this point, however, engineers were not so unanimous, and a discussion arose as to the relative merits of the two systems and many tests were made to determine which was the most economical way, these comparisons generally being drawn between the so-called *group system* and *individual-motor system.*

This method of comparison while in general not unfavorable to the individual motor was not conclusive, for the reason that the item of power is a small one in most manufacturing establishments, and a very great saving must be effected by any system to make economy a determining factor. To illustrate: An electrical manufacturing establishment, and these are heavy users of power, employing say 1,000 men would require at least 500 H.P., which, with coal at $6.00, would cost about $9,000 or $10,000 a year. The output of such a place should be in the neighborhood of $1,500,000 at factory cost. The question of economy alone was not sufficient to settle the problem, but out of the discussion came much valuable data and some well defined principles. It was clearly shown that conditions exist where either or both systems have a place, and that again conditions may exist where neither are desirable, as in cases where heavy machinery is to be operated close to the prime mover, as in certain kinds of mills driven by water wheels.

The plant must be very small and compact, however, when electric distribution cannot be used to advantage, and in large plants it is indispensable.

It is also now conceded by engineers in general that large and portable tools can be best driven by individual motors, and the greatest bone of contention in this regard is the question of just how far individual driving should be used as against group driving, with a gradual growing sentiment in favor of the individual drive.

That the individual drive has not met with more favor was due in the past mainly to two causes:

(1) Imperfect motors.

(2) The general attitude of machine-tool builders.

When motors were first introduced in this work electrical designers had not studied the peculiar problems presented, and as a consequence the first motors were not very satisfactory. The machine-tool builder, on the other hand, saw at once that the motor was going to impose a new set of conditions on these machines, compelling him eventually to alter his patterns; and many of them naturally did much to discourage what some of them characterized as a fad.

As might be expected, the combinations designed under these circumstances were fearful and wonderful. A standard gas engine fastened to an ordinary carriage would not make a very good automobile; yet in comparison it would show up well with some of these early efforts.

But these difficulties are now being rapidly overcome. Machine-tool builders and electrical men are getting together on the problem, and it will not be long till growth or consolidation will give us a machine company which will make a specialty of turning out complete motor-driven tools. When that time comes, and only then, will the individual drive reach its highest development and lowest production cost. The latter item will have a great bearing on the final adjustment of the question of group drive versus individual driving, as will be seen later. In the meantime it is possible to buy almost any machine tool, motor driven in some way, although not always in a very desirable manner.

With these general principles established the engineer is confronted with the problem of connecting up his electrical system of distribution to his medium-size and small machines, and in making his decision as to the method to be used he will be governed largely by the following considerations:

(1) First cost of installation.

(2) Maintenance and depreciation.

(3) Provision for extension.

(4) Sectional operation.

(5) Flexibility as to location of tools.

(6) Efficiency of system.

(7) Positive application of power.

It may be well to consider these points in some little detail.

(1) Undoubtedly the first cost of individual driving is considerably greater than group driving, and, unless it can be shown that the individual drive has great advantages in other ways which offset this important item, it is not likely to be considered by the man supplying the money. This is often a very difficult thing to do, and first cost will remain a drawback to the motor drive for small tools till different conditions of manufacturing reduce the costs considerably from where they stand at present.

(2) On the second point we have as yet not a great deal of data that the writer is aware of, but his experience has been that the cost of maintenance and the depreciation was somewhat less in group driving. In the group drive the great item of expense is that of belting, which is costly and wears out rapidly; on the other hand, when motors do need repairing the repairs are costly, so that, on the whole, there does not seem to be much choice. Reliable data on this point would be of great service.

(3) Regarding the third point, the individual drive has all the advantage. No system has ever been devised that provides so easily for extension. Changes in arrangement are also more quickly and easily made with the individual drive.

(4) Here, again, the advantage is all with the individual drive, particularly with large tools which may be required to run overtime. Further, the breaking down of an individual motor does not affect but the one tool. This last, however, is not of great importance, as the motors now built are quite reliable.

(5) On this point the individual drive has an advantage that is particularly important. Machines so driven can be placed wherever desired, and in case of large tools, ideal con-

ditions are obtained for overhead-handling devices. In the case of small tools greater convenience can be obtained and tools can be placed in the middle of the room without cutting out the light. Incidentally, the elimination of belts on such a floor greatly decreases the dust.

(6) The question of efficiency has already been discussed and needs no further comments here except that it has been found by actual measurement that there is little to choose between group and individual driving, as far as efficiency is concerned.

(7) The seventh and last point is the one on which the individual drive has its greatest claim to superiority, and which has done more for the individual drive than anything else. It was soon found that where motors were directly geared to the machine a greater output was possible on account of the elimination of the slip in the belt, and the consequent driving of the work up to the limit of the cutting tool. This, of course, greatly reduces the time of the operation, and, as the cost of the time is two-thirds the total cost of the product, it is easy to see what a saving could be effected. The introduction of the new high-speed steels added still more to the necessity of positive driving, and it has been well demonstrated that where heavy cuts are to be taken the positively-geared motor will show a great saving of time over the belt drive.

Herein, also, lies the solution of the problem so confusing at present to the engineer who is trying to find out just how far he can carry the individual-motor-drive idea and make it pay. In the case of large tools, it will be seen at once that the solution is plain, and a careful consideration will show that the individual drive can be successfully used down to a point *where a belt of convenient size will have no trouble in driving the cutting tool up to its limit.* Rules which fix some particular limit to the minimum size of motor to be used or the minimum size of machine to which a motor should be attached are very misleading, as it depends entirely on what the tool is intended to do. For instance, a group of 16-inch lathes in one shop may be required to only take off a very

light chip and a group drive is all right. In another shop these lathes may have heavy work so that a motor drive will pay handsomely. There is no trouble, as a rule, in driving small drill presses up to the limit of the drill by means of group drive, and these are driven successfully in this manner; the same being true of small tools in general. At present it will not pay, outside of the advantages of better light and cleaner surroundings, to drive very small tools individually; but the writer believes that cheaper motors and properly-designed tools will make the size of tool smaller and smaller till eventually it will be the prevailing system. At present each case must be worked out on its merits along the lines suggested above.

	Group Drive.	*Individual.*
1. First cost	Considerably less.	
2. Maintenance and depreciation	Probably less.	
3. Provision for extension		Much superior.
4. Sectional operation		Much superior.
5. Flexibility as to location		Much superior.
6. Efficiency of system	Not of great consequence.	
7. Positive application of power		Much superior.

Having decided what tools to drive individually and what to group drive, the next question is the matter of motors and the methods of connecting them to the machines. Here, again, a great difference of opinion exists and much conflicting literature has been written. In order to get a clear idea of what is needed in a motor for this work it will be well to look at the requirements of the tools themselves.

Machine tools may for this purpose be classified into the following groups:

(a) Machines requiring a constant speed. In this class come punches, shears, fans for ventilating purposes, and also the shafting of group drives. The torque may vary with the demand for power.

(b) Variable-speed machines requiring maximum power at minimum speed. In this class are lathes, boring mills and most machine tools where automatic regulation is needed.

Here the cutting speeds are practically constant for a given metal, but the cuts are larger on the larger work.

(c) Variable-speed tools requiring heavy starting torque, as cranes, sheet-iron rolls, etc., where regulation of speed is by hand.

(d) Machines requiring a torque increasing with the speed, as blowers and fans which give variable blast. This class is rather unimportant and will not be discussed.

Of course there is no trouble in meeting the requirements of the constant-speed machines, but the problem of variable speed is as old as the hills. If a good mechanical speed-changing device were to be had, the problem would be easy to solve. But so far none have been produced that will answer the purpose. Many have been made that will give any speed between the limits of the mechanism, but they all depend on friction, and hence to carry the work required must in most cases be very large and cumbersome; while those that are positive in their action give only several speeds between the limits and hence are not all that is desired. Of the latter type a number are now on the market which can be used with success in many places.

When the electrical side of the problem is considered a choice of two distinct systems of distribution is presented, namely, the alternating-current, and the direct-current systems, both of which have a place under proper circumstances in this work.

It may be said at the outset that when the alternating-current system of distribution can be used it is preferable, as the wiring is smaller in a large system, the generators and motors simpler and more reliable. It has, however, its limitations, as will be seen, as far as machine-tool driving is concerned.

The alternating-current system offers two kinds of motors, the synchronous and the induction motor. The first is not self-starting and, except in a few cases, has no place in machine-tool driving. Where heavy shafts as test shafts are to be run for some length of time and provision can be made for starting, a synchronous motor is an excellent thing in con-

nection with induction motors, as it tends to steady the line and help the power factor. In small sizes, however, it is not suitable for machine-tool driving.

The induction motor is self-starting, and, like the synchronous motor, tends to run at constant speed. It is by its nature not a variable-speed machine, although it can be made so in several ways, none of which, however, have so far proved adequate to the demands of machine-tool driving. It has been successfully used on cranes and similar devices, the speed variations being obtained by putting resistance in the secondary, and variable-speed induction motors are now on the market controlled in this manner. One plant, at least, has been fitted out with induction motors, where several changes of speed were obtained by varying the frequency, with fair success. But as yet the induction motor cannot be considered as equal to the direct-current motor for variable-speed work, though considerable experimental work is now being done that may change the situation.

If the plant under consideration is to contain constant-speed machines principally, the induction motor in connection with a mechanical speed-changing device will generally prove to be the best, and where all the machinery is of constant-speed type it is much preferable. Of course local conditions may effect this, as for instance, when the power is to be bought and only direct current is available.

The direct-current system offers three kinds of motors, their combined characteristics covering much more closely the requirements of the case than do those of the alternating motor, and there is little doubt as to the greater adaptability of the system for general machine-tool driving. These motors are (1) series-wound motors; (2) compound-wound motors; (3) shunt-wound motors.

The series motor is a variable-speed motor with great starting torque. It can be controlled throughout its whole range of speed and would seem at first glance to be almost ideal for lathes and boring mills. It is, however, very uneconomical, as the control is obtained by resistance in its circuit. It also

requires an expensive controller on account of the heavy current to be handled, and must be controlled by hand, as its speed varies inversely with the load, and under light loads it will run away. It is an excellent motor for cranes, elevators, sheet-iron bending rolls, etc., and occupies a very important place in the equipment. It therefore covers the requirements of the tools under class (c).

The compound-wound motor is suitable where small variations of speed are needed coupled with a large starting torque. It will, of course, give constant speed when set for any set of conditions within its range.

The shunt motor is, in its standard form, a constant-speed motor. When set to run at a given speed it will not vary appreciably under varying load up to its capacity. It can be made to vary its speed in a number of ways, those which are most used being one of the following three:

By varying the current in the armature.

By varying the strength of the field.

By varying the voltage applied to the armature terminals.

These characteristics make the shunt-wound motor most suitable of any for the purposes of machine-tool driving, and by means of these methods of control, either singly or in combination with each other or in combination with gearing, most of such work is now accomplished.

Class of Machine.	*A. C. Motors.*	*D. C. Motors.*
Constant speed, torque varying with load.	Induction motor. Synchronous motor.	Shunt or compound-wound motor.
Variable speed, max. work at minimum speed, automatic regulation.	Induction motor with mech. speed-changing device.	Shunt-wound motor with or without change gears.
Variable speed. Heavy starting torque. Hand regulation.	Induction motor.	Series-wound motor.
Variable speed, torque increasing with speed.		Comp.-wound motor.

A discussion of the principal methods of speed control may be of interest. If the armature current in a shunt-wound motor be decreased by inserting resistance, the field remaining

constant, the speed of the motor will decrease. But when this method of control is used the motor loses one of its most valuable qualities. It will no longer run at constant speed under varying load. Besides, this method of control like that of the series-wound motor is very wasteful, and the controller must likewise be large and complicated to handle the large current which must be broken. This method, therefore, has ceased to be used to any great extent.

If the field strength of the shunt motor is varied the speed will vary accordingly, and in this method of control the bad features of the above method do not appear. The field current is small and therefore the resistance loss small and the controller simple and cheap. The motor likewise retains its good quality of steady running. The power, however, falls off, for now the commutating ability of the field has been decreased, so that less current can be passed through the armature. In order, therefore, to get a given output at higher speed with field control the motor must be larger than one built for the same output at the normal fixed speed.

To illustrate: A 4-H.P. motor at 400 R.P.M. will only give 1-H.P. at 1,600 R.P.M. with field control. It will be seen at once that in order to get a large range in this manner the motor must be very large. It will be noticed, however, that the characteristic of the motor fits the requirements of tools in class (b), and it is therefore much used for driving this class.

If the field strength is kept constant and the impressed volts at the armature terminals be varied the speed of the shunt-wound motor will vary accordingly. Theoretically this is a most excellent method of speed control, as it allows the use of a smaller motor than in the method of field control, and the efficiency of the motor at the various voltages is high. In practice, however, the number of voltages that can be supplied is limited, and therefore in its simplest form the system has the same defect as the method of controlling alternating induction motors by changing the frequency. It is usual, therefore, to make the motors large enough to have field control sufficient to reach between voltages, which makes a system

that completely covers the range between voltages and extends the range beyond the speed normal at highest voltage.

To illustrate: Suppose the range is 4 to 1, as before, and let the voltages be 60, 80, 110, 140, 190, 250, as used by the Bullock Co. in their four-wire system. Let the minimum rate at which power is required be 1 H.P., as before. Neglecting losses, this range of voltages alone would give six fixed speeds, and if, as before, the lowest is 400, the fastest would be about 1,600, or directly proportional to the voltages applied. The motor for the system would only need to be 1 H.P. at 400 R.P.M., instead of 4 at 400 R.P.M., as in the case of shunt field control. If now the motor is made large enough to stand an increase of speed by field control of about 33 per cent., it can be speeded up in that way from voltage to voltage and the whole range covered. Further, when running at 1,600 R.P.M. at 250 volts, it can still be speeded up to 2,133 R.P.M., making the total theoretical speed range 5 to 1.

Undoubtedly this system works well, but, like all the others, has its defects. It is not desirable to carry high voltage round manufacturing plants for obvious reasons, so that in order to get a large range in this manner the lowest voltage must be very low. To obtain the full output at low speed, and it has been seen that generally the greatest output is required at the lowest speed, the current must be increased; so that the expense of wire runs up rapidly for wiring the low voltages, or if the mains are kept down in size the line losses are heavy and the impressed volts drop off, the motor slowing down accordingly. Further the obtaining of only six voltages by a four-wire system introduces considerable complication, as is easily seen, besides the extra expense for controllers, wiring, and the machines for giving the various voltages. A description of the latter is beyond the scope of this article. Generally a motor generator set of some form is run from the main series of the principal generating set which splits the voltage of these mains. Thus a 250-volt circuit can be divided by

two wires from such a set into 60, 80 and 110-volt steps and the combinations of these give six voltages.

If a three-wire system, giving, say, 110 and 220 volts, is available a speed range of 4 to 1 can be obtained in the following manner: Let the data be the same as above, and then for this case the motor will be a 2-H.P. motor at 220 volts and 800 R.P.M. When running on 110 volts and full field it will develop 1 H.P. at 400 R.P.M. Since the motor is running below normal speed it can be speeded up through a considerable range and still commutate well. By this means probably 60 per cent. increase can be obtained with the ordinary motor, when the voltage must be changed to 220 and full field applied for any further increase. On the higher voltage the field can be again weakened till the speed is doubled, and at 1,600 R.P.M., as the motor is now large for the work to be done, it will commutate all right.

In order to make a close comparison with the other systems this motor should be somewhat larger, say 3 H.P. at 220 volts or 1½ H.P. at 110, so as to cover by field control the whole range from 400 to 800. In such a case, however, a further increase in speed could be made when running on 220 volts, thereby extending the range somewhat.

If it is not desired to use the excessively large motor resulting from entire field control or the complication of multi-volage, a combination of field control and gearing can be used. Using the same data as before, the motor could be designed for a field control of 2 to 1 and a single set of change gears used in combination with it. Here the motor would be a 2 H.P. at 800 R.P.M., giving 1 H.P. at 1,600, and not exceeding the speed limit originally assumed. This method, which is a compromise between the other systems, has many good points. The wiring and generating system are simple, as only a single voltage is necessary, and the motor need not be excessively large for the work, as it can always be worked at the maximum range of speed which is allowable for gear connection. The voltage is always the highest permissible, hence the wiring is small, and while the multi-voltage system

gives somewhat quicker change of speed the difference in well-designed machines will not be very great.

In the writer's opinion it is a logical system and will be very widely used in machine-tool work mainly on account of its electrical simplicity. The efficiency of such a system is good, and if the gearing is properly designed the range covered by the motor alone need not be great enough to make it large and clumsy.

The table shows the relative sizes of the motors which must be used in the systems described above to cover the range from 400 to 1,600 R.P.M. and with a maximum voltage of 240. It will be seen that the motor with 2 to 1 field control and a single set of change gears is the smallest, requiring three ampères, approximately, when delivering 1 H.P., against six in the case of the multi-voltage at same speed. The figures for current used are, of course, approximate, and are for the purposes of comparison only.

To get the lower range of speed, *i. e.*, 400 R.P.M., the change gears with ratio 2 to 1 would be thrown in and the motor put on full field, when it would run at 800 R.P.M. By decreasing the field strength its speed would be raised to 800, when the gears would be thrown out and the motor again put on full field. The further increase to 1,600 would be accomplished by again weakening the field.

Motors giving successfully a range of 2 to 1 by field control are at present not classed as standard motors, although there is no difficulty in obtaining them or motors which will give a much greater range. This distinction will, however, disappear as they are more widely used, and there is no reason why motors giving such a range or greater cannot be made as a standard product if the demand is sufficient. A number of makes are now on the market which offer a much greater range than this, but at present, as shown by the table, it would not seem advisable to go far beyond 2 to 1, except, perhaps, in special cases.

Some of the special methods adopted to insure sparkless

commutation under increased speed with field control are worthy of notice.

In the Thompson-Ryan motor the armature is surrounded by a set of stationary coils called "Balancing Coils," running parallel to the armature winding and in series with them. These coils not only neutralize armature reaction and prevent its distorting effect, but also build up a commutation field independent of the shunt field. The latter can, therefore, be weakened beyond the limits of the ordinary motor and yet good commutation will result. This firm are now advertising a line of motors having a speed range of 6 to 1.

In the Stow and Story motors a hollow pole is used which has the effect of concentrating the field nearer the outside of the poles, hence the commutating field is stronger when weakened than in the ordinary form of motor. Of course, the general principles already discussed regarding the relative sizes of motors under various conditions hold good, also, for all these forms.

System.	400 R.P.M.			800 R.P.M.			1,600 R.P.M.		
	Max H.P.	Cur'ent for H.P.	Volts.	Max. H.P.	Cur'ent for H.P.	Volts.	Max. H.P.	Cur'ent for H.P.	Volts.
4 to 1 field control	4	3	240	2	3	240	1	3	240
4-wire multi-voltage	1	12	60	2	6	120	4	3	240
3-wire multi-voltage	1½	6	120	3	3	240	1½	3	240
2 to 1 field control with 2 to 1 gearing	2	3	240	2	3	240	1	3	240

Column 1 under each speed gives maximum H.P. motor will give. Column 2 gives the ampère per H.P.

From the foregoing it is easily seen that the range of any of the above systems of speed control is somewhat limited, the four-wire multi-voltage having the widest for the same size motor. But even this is limited as here laid down to about 6 to 1 when using field control on the highest voltage. It is true that it can be extended by using either higher or lower voltages, both of which are undesirable. Now machine tools which require variable speed may have a range as high as 50 to 1. An ordinary 16-inch lathe, belt drive, would have a range of 12 or 16 to 1, and while, no doubt, many tools are

furnished with greater range than absolutely necessary, 6 or 8 to 1 being found sufficient for many purposes, at present it is easily seen that none of the systems outlined will conveniently cover such ranges. Resort must, therefore, be made in most cases to gearing to finish out the range even with multi-voltage. When the range to be covered is very great this last system has an advantage, but for most machines the range required can be covered with a field control of 2 to 1 and two sets of gears, and for the larger ranges which are not so frequent a field control of 3 to 1 can be successfully used.

Where a three-wire system is already installed the application of variable-speed drives is easily accomplished by the system outlined above. But when the case of a new plant is under discussion, careful consideration should be given to the foregoing principles, and the system selected should depend largely on the ratio of variable-speed tools to constant-speed tools. If the plant is large enough an alternating system with proper transforming devices might prove the best, and, in the writer's opinion, many large plants now equipped with direct-current distribution would be much more economically run if so provided.

FINE GUNS.

The maximum efficiency of the 12-inch gun has not yet been secured, in England at any rate. From all accounts the finest 12-inch gun in the world at present is the new model French 12-inch, which is being mounted in the *Danton* class. It is said to be equal to penetrating 12-inch K.C. at 8,000 yards. The special feature of this gun is a much heavier projectile than heretofore employed.

There are rumors of an extremely fine 11-inch Bofors gun, destined for the Swedish navy. Its main feature is said to be a fine penetration at long range. So far as we can ascertain, this is the gun with which it is proposed to arm the small *Dreadnoughts* that Sweden is credited with projecting.

THE CORROSION OF STEEL.

By ALLERTON S. CUSHMAN, Assistant Director Office of Public Roads, United States Department of Agriculture.

Iron is unique among the elements, not only on account of the ease with which it dissolves or combines with nearly all other elements, but also on account of the changes in structure and physical character which are produced by the presence of almost infinitestimal quantities of impurities. A variation of a few tenths of one per cent. in the amount and condition of the carbon content may produce such a change in the physical properties of the metal as to alter entirely its fitness for the various purposes to which it is put. A variation of a few hundredths of one per cent. of phosphorus in the specifications for certain useful forms of steel has been and still is a matter of controversy between interests representing hundreds of millions of dollars of capital and involving questions of the safeguarding of the lives and property of the public. Sulphur, silicon and manganese are among the other well known elements whose presence or condition in extremely small amounts produces important differences in the character of steel. Absolutely pure iron has but a limited use in the industries of man, and as a rule the properties which are sought are produced by the presence of other elements.

This point is emphasized in order to call your attention to the fact that, chemically speaking, structural iron or steel is not a standard substance, but varies in composition and in character.

I have frequently called attention to the fact that resistance to corrosion was one of the most variable of the many characteristics of steel. That is to say, not only do the various kinds of merchantable iron and steel differ from each other within the wide limits in their resistance to corrosive influences, but specimens from the same mill or furnace will frequently show a great difference in this respect. There are few subjects at the present time more important to the engineer and the architect than the protection of structural steel

from rapid, unsightly and dangerous corrosion. I wish to point out that there are two separate and distinct lines along which we may hope to make progress.

The first of these has to do with the understanding of the causes which promote corrosion and their elimination in the manufacture of the metal, and the second is the study of paint films or waterproof coatings which shall really protect even the most inferior metals for indefinite periods. It is only the first phase of the subject that I shall consider to-night.

The tendency to oxidation is a characteristic inherent in iron, and an absolutely unrustable iron or steel will probably be impossible of accomplishment, even in the distant future. If, however, all the steel made resisted corrosion as well as the best of it, there would be no problem, and this paper would not have been written.

I shall not take your time this evening to review the older theories which were held to account for the rusting of iron, but will call your attention to the electrochemical or electrolytic explanation, which is now coming to be generally accepted. According to modern chemical theory, all reactions which take place in water solution are attended by certain readjustments of the electrical states of reacting particles which are called ions. You are undoubtedly aware that under the atomic theories molecules of compound substances are made up of atoms which are held together by a force or forces which represent large amounts of energy. Now, some substances, when they are dissolved in water, will conduct electricity, while others will not. The first class of substances which are generally inorganic acids, alkalies and salts, we call electrolytes, while those organic bodies, such as sugar, which do not conduct electricity in solution, are non-electrolytes.

Arrhenius, a Swedish physicist, in 1887, announced the theory of electrolytic dissociation, the evidence for which can not be discussed here, but it can be said that the theory has been borne out by numerous researches, and is at the present time almost universally accepted. This theory tells us that

the molecules of electolytes, as they pass into solution in water, dissociate into ions which are simply atoms carrying, in spite of the smallness of their mass, very heavy charges of electricity. In order that no energy may be lost or gained, it follows that the dissociation must produce both positive and negative ions, which are equivalent and opposite. A rough analogy of what has taken place through dissociation is furnished by a coiled-steel spring. If we put such a spring in tension and hold it thus, without addition or subtraction of material, we have impressed potential energy upon it, which will be returned in equivalent amount when by any means the tension is relieved. Indeed, we might consider one end of the spring as positive to the other end, and that in relieving the tension the energy reappeared by the neutralization of the positive and negative potentials.

To illustrate further what is meant by the theory of solutions, let us consider the system common salt and pure water. Common salt is composed of an atom of sodium combined with an atom of chlorine, and the molecule is represented by the simple chemical formula Na Cl. When sodium chloride is brought together with water it tends to go into solution, the molecules mingling with the molecules of the water, owing to a force known as solution pressure. As an increasing number of molecules appear in solution, however, a back pressure is exerted which to a constantly increasing extent resists the entrance of more molecules. This reverse action is known as osmotic pressure and it is perfectly clear that if an excess of salt is present the end of the action will come about for any definite temperature just as soon as the osmotic pressure and the solution pressure are equal. But in addition to this the very important action takes place which has been just referred to. In passing into solution the salt dissociates into its constituent ions, which simply means that the solution forces tear apart the associated atoms, and the energy which held them together appears in a potential form as equal and opposite charges of static electricity on the ions. So that the solution of salt in water is represented by the equation :

$$Na\,Cl \longrightarrow \overset{+}{Na} + \overset{-}{Cl},$$

in which $\overset{+}{Na}$ and $\overset{-}{Cl}$ represent the constituent ions. Osmotic pressure, however, acts against the dissociation pressure just as it does against the solution pressure, so that in concentrated solutions we have a reverse action also taking place represented by the equation:

$$\overset{+}{Na} + \overset{-}{Cl} \longrightarrow Na\,Cl.$$

Chemists therefore say that the state of equilibrium for the system we are considering can be expressed by the reversible reaction:

$$Na\,Cl \rightleftarrows \overset{+}{Na} + \overset{-}{Cl}.$$

Now, bearing these simple details of the modern theory of solution in mind we may return to the consideration of the reactions which take place when iron rusts. If a bright strip of iron is immersed in a solution of a copper salt, such as the sulphate, iron goes into solution and copper plates out on the iron. The reason for this is that the solution pressure of the iron is greater than that of the copper ions, therefore iron passes into solution, the positive static charge being transferred from the copper ions to the iron ions. This reaction is simply written:

$$Fe + \overset{+}{Cu}\,.\,\overset{-}{SO_4} = \overset{+}{Fe}\,.\,\overset{-}{SO_4} + Cu.$$

Now if we leave out the copper sulphate in this system, and immerse the strip of iron in plain water, a similar reaction takes place. It is known to chemists that even the purest water is to a slight extent dissociated, and therefore contains hydrogen ions. That is to say, while water consists mainly of molecules written H_2O, there also are present positive hydrogen ions $\overset{+}{H}$ and the equivalent negative hydroxyl ions OH. Hydrogen acts as a metal and has a solution pressure somewhat less than that of iron. Therefore, when iron is by any means whatever brought into contact with water it will, to a

certain extent, pass into solution by exchange with hydrogen. This reaction, upon which all forms of corrosion are primarily based, may be written :

$$\mathrm{Fe} + 2\overset{+}{\mathrm{H}} \,.\, \overset{-}{\mathrm{O}}\mathrm{H} = \overset{++}{\mathrm{Fe}} \,.\, \overset{-}{\mathrm{O}}\mathrm{H}.\overset{-}{\mathrm{O}}\mathrm{H} + 2\mathrm{H}.$$

It has been shown experimentally that iron cannot, at ordinary temperature, combine with oxygen unless the iron first passes into solution, and it is apparent from this that the initial cause of rusting is not oxygen, but hydrogen, bearing a static electrical charge, in other words, the hydrogen ion. Now all acids derive their character from the fact that they dissociate in solution with the production of hydrogen ions, and this is the reason why all acids stimulate the corrosion of iron. On the other hand, alkalies dissociate in solution with the production of hydroxyl ions, which, by the reverse action already explained, neutralize and remove the hydrogen ions and thus inhibit rusting.

It is well known to engineers that sulphurous acid, as well as carbonic acid, from coal smoke produces rapid destruction of steel, whereas alkaline cements, mortars and concretes will preserve steel imbedded in them so long as the reaction remains sufficiently alkaline. The only cases recorded in which steel is said to have corroded when imbedded in concrete are those where percolating water under pressure has washed away the free lime and thus removed the alkaline reaction.

We may now turn to the rôle played by oxygen in the rusting of iron. Iron is one of those elements which exists in more than one state of combination with oxygen. The least oxidized state is called ferrous, while the higher state is called ferric. Oxygen always changes ferrous to ferric compounds. Iron, having once appeared in solution in the ferrous condition by exchange with hydrogen, is at once attacked by oxygen and precipitated at the point of attack in the form of the insoluble hydrated ferric oxide which is known as rust. This statement is easily proved by experiment, for all solutions of

ferrous salts are directly oxidized or rusted by standing in the air. The rôle of oxygen is therefore secondary, but it is none the less important, for the simple reason that by precipitating the insoluble rust the iron ions are destroyed and removed from solution, thus lowering the osmotic pressure and making room for more to be formed. The scientific explanation would be that the appearance and precipitation of the solid phase (rust) lowers the osmotic pressure, thus enabling the iron, driven by its solution pressure, to pass rapidly into the ionized condition.

To sum up, then, as far as we have gone, the rusting of iron is caused, first, by the solution of the metal by exchange with hydrogen, and secondly, by the action of oxygen on the dissolved portion, both actions being accompanied by a transfer and neutralization of electric charges on the reacting atoms or ions.

The next important point is that the solution of the iron does not, as rusting proceeds, take place uniformly over the exposed surface, but on the contrary the solution is stimulated at certain nodes or points and inhibited at others. To this direct local electrolysis is due the peculiar form of corrosion known as pitting, which is almost always observed when iron and steel are deeply rusted.

The fact that iron does not tend to go into solution uniformly and evenly all over the exposed surfaces, but passes rapidly into solution at certain surface points, can only be interpreted in one way; namely, that local electrolysis is taking place.

Now, applying what has already been said, it follows that as each iron ion appears in the solution a hydrogen ion must leave the system in order to maintain the equilibrium and so that no energy be lost or gained. It follows from this that hydroxl ions must be left behind as the hydrogen changes into the gaseous form and disappears, so that we should expect to find a congregation of iron ions at one pole in the electric circuit and hydroxl ions at the other. Owing to the formation,

then, of these local electric couples, the surface should be protected at the negative poles around which the alkaline hydroxl ions cluster, and attacked at the positive, where the iron is passing into solution, and being acted upon by oxygen.

Now, this action can be easily made visible as it takes place by means of a special indicator to which the writer has given the name ferroxyl. There is a certain reagent called potassium ferricyanide that forms a beautiful blue color, known as Turnbull's blue, when it comes into contact with ferrous ions. There is also an organic substance known as phenolphthalein which makes a rose-pink color with hydroxl ions. Specimens of steel immersed in a solution of these mixed substances, and stiffened with agar-agar jelly so that they cannot shake about, invariably show blue and red nodes, proving beyond all doubt the development of positive and negative nodes as corrosion proceeds.

Time will not allow of the presentation of a full discussion of the proofs that have been given to show that the corrosion of iron is always due to local electrolysis on the surface of the metal itself. The subject has been presented in detail in a bulletin recently issued by the Department of Agriculture. One of these demonstrations will, however, probably be of interest here.

When a section of rolled metal, such as sheet or plate, is immersed in water, if the electrolytic theory is correct, rusting must take place with the establishment of positive and negative spots or areas. At the positive points iron will pass into solution and be rapidly oxidized to a loose, gummy, or so-called colloidal form of ferric hydroxide which is characteristic of rust formed under these conditions. It is a well-known fact, as has been proved by experiment, that colloidal ferric hydroxide will move or migrate to the negative pole if subjected to electrolysis. We may therefore consider the possibility of two separate effects that may be produced, viz: when a positive center is surrounded by a negative area, and vice versa. These two conditions may be graphically represented by the two circles A and B:

Now, as rusting proceeds we should expect in the case of A that the ferric hydroxide would be piled up in a crater formation, while the metal is eaten out at the center. In the case of B the effect would be reversed, and while the metal would be attacked in the surrounding area the hydroxide would be piled up in a cone at the center. That this is precisely what is taking place whenever a sheet of metal rusts under water a low-power microscope very clearly shows.

The photomicrographs in which the craters and cones are clearly shown have been published in the bulletin referred to above.

If you are willing to accept the electrolytic theory of corrosion you will very naturally inquire in what respect does it point the way to an improvement in the conditions as they exist at the present time. It follows from what has been said that the more carefully lack of homogeneity and bad segregation are guarded against during the processes of manufacture the less likely is the metal to suffer from rapid corrosion. If the iron contains metallic impurities dissolved in it, such as manganese, which differ electrochemically from iron, trouble is sure to ensue if there is a lack of homogeneity in the distribution of the impurity. In the old days when iron was made more slowly and received more careful working than is possible in the present day, serious corrosion was not the important problem it has since become.

The writer has in his possession a hand-forged nail, still in good condition, which was driven in the old Masonic Hall at Richmond, Virginia, in 1807, and for a long portion of time has been freely exposed to the weather. There is a widespread opinion, which the writer shares, that the old wrought or puddled iron of thirty years ago is more resistant to corrosion than most of the modern steel.

But the interesting point is that modern steels vary so widely from each other. Here are two pieces of angle steel

which constituted two members of a signal bridge on the Boston & Maine Railroad erected in 1894. These members were only six feet apart in the structure, and the conditions of environment, exposure and care were precisely similar, and yet one is corroded to the condition of lace work while the other is hardly touched. The chemical and microscopical examinations of bright samples cut from these two specimens does not show any essential differences, both contain about 0.5 per cent. of manganese, and yet electrolysis has proceeded rapidly in one and almost not at all in the other. Does it not seem probable that the ingot, or portion of ingot, from which one of these members was rolled differed in segregation or in chemical homogeneity from the other? At all events, if all the members in this bridge structure had been as good as this best one they would still be in service instead of on the table before you. It is of the utmost importance that we should learn to control the resistance to corrosion of structural steel, and to this end we should unite to urge upon manufacturers the necessity of making special efforts in this direction.

It would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities or should be, by careful working and heat treatment, rendered so homogeneous as not to retain localized positive and negative nodes for a long time without change.

Manganese is an element which is almost always associated in modern metallurgy with iron and steel, owing to the fact that this element is used as a flux in the great processes used today for changing cast iron into steel. Manganese, however, increases the electrical resistance of iron, and as the percentage of this element, starting from zero, rises, the electrical resistance of the metal increases up to a certain specific maximum. Now, you will see, if the dissolving of manganese in iron raises the electrical resistance, that any changes in the equilibrium or distribution of the manganese in the

metal means that there will not be an even or homogeneous electrical conductivity throughout the mass.

If we have a metal in which the electrical conductivity for any reason varies from point to point on the surface we have the precise conditions which are necessary in order to establish the local nodes of electrolytic action on the surface which lead to rapid corrosion. It is apparent, therefore, that if we are to allow the presence in structural steel of comparatively high percentages of metallic impurities, such as manganese, we must attempt to obtain an extremely homogeneous distribution of such impurities. It is for this reason, principally, in the opinion of the writer, that the more quickly and more carelessly the metal is manufactured and rolled, the more quickly it disintegrates under corrosive influences. As has been pointed out before, there are two methods of meeting the problem: first, to keep the percentage of metallic impurities as low as possible, and secondly, to guard against segregation and imperfect chemical homogeneity in the metal. In experiments we have made looking to the manufacture of a corrugated-steel culvert for use in road building, it has been found by the author that corrugated metal, running as low as .04 manganese, has been more resistant to the corrosive test employed than the ordinary steel of the day, which usually carries about .5 per cent. of manganese. Material of this kind has not been available for a sufficient length of time to determine whether under service conditions this low-manganese metal will be longer lived, but it can safely be stated that the indications are all in its favor.

The writer has urged the manufacture of manganese-free steel for certain purposes, not because manganese is necessarily the cause of rapid corrosion, but because this impurity enables the metal to be rolled more easily and more cheaply, and in many cases permits the working in of large amounts of heterogeneous scrap. It is possible to manufacture shoddy steel as well as shoddy cloth, and though both of these materials have their legitimate uses for certain purposes, no one will claim for them high resistance to disintegrating influ-

ences. It is a hopeful sign of the times that manufacturers are beginning to pay serious attention to the manufacture of iron and steel for certain purposes which shall be to the highest possible degree rust proof.

Considerable attention has been given to the peculiarly passive condition that can be induced on the surface of iron by contact with solutions of certain oxidizing agents.. Without going into the details of this phenomenon, which have already been published, I will refer briefly to the peculiar action of chromic acid and its salts. Polished specimens of steel may be kept indefinitely without suffering corrosion when immersed in a dilute solution of potassium bichromate. On first thought it would seem a paradox that a strong oxidizing agent should have the effect of preventing the oxidation of iron, and yet this is the case.

According to the theory of the writer, the oxidizing agent polarizes the surface of the iron to the condition of an oxygen electrode, so that it is immune from the attack of the hydrogen ions; thus the whole electrolytic process is checked or inhibited. A curious feature of this action is, that it is to a certain degree persistent after the metal has been removed from contact with the oxidizing solution, washed and wiped. This phase of the phenomenon requires further study, but at the present time it does not appear probable that the induced passive condition can be maintained on the surface to an extent that would make it of practical value for treating structural steel. With regard to the preservation of boiler tubes, and for certain special purposes, it is not unlikely that a practical application of these principles will be found.

In conclusion it may be said that there is reason to hope that the time is not far distant when specifications may be drawn for material that is going into service under conditions which make it particularly subject to corrosive influences. The possible added cost of such specially-resistant metal will be small in comparison to the benefits which will be derived from its use in the long run.

SHIPS.

ENGLAND.

H. M. Battleship Lord Nelson.—The latest battleships added to the British Navy are the *Lord Nelson* and the *Agamemnon*, the former built by Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne, and the latter by Messrs. William Beardmore & Co., Limited, Dalmuir. The latter has been commissioned, and is attached to the North Sea Squadron; the former has completed her trials, and will also go to the Nore. The *Lord Nelson*, is, like her consort, 410 feet long, 79½ feet beam, and has a displacement of 16,500 tons at 27 feet draught. They differ from the *Dreadnought* in their armament. Whereas the latter has ten 12-inch guns, the *Lord Nelson* has four 12-inch and ten 9.2-inch guns, and this latter combination is approved by many owing to the greater rapidity of fire of the 9.2-inch guns. Against this, however, is the lower muzzle energy and the consequent reduction of effective range. The vessel is heavily armored. The *Lord Nelson* was engined by Palmer's Company. The machinery includes twin engines of the four-cylinder triple-expansion type and Babcock & Wilcox boilers. The results of the trials, recently completed, are tabulated:

......	Eight hours. Full power.	Thirty hours. Four-fifths power.	Thirty hours. One-fifth power.
Indicated horsepower	17,445.0	12,232.0	3,624.0
Coal per indicated horsepower, lbs	1.99	1.98	2.23
Steam pressure, pounds	234.0	241.0	231.0
Vacuum, inches	25.3	27.3	26.7
Revolutions	125.2	113.2	75.8

The designed power was 16,750 horsepower, which, it was anticipated, would give a speed of 18 knots; the actual speed was nearer 19 knots.

The British Cruiser-Speed Record for the year is held by

the *King Alfred*, which on her eight-hours' sea trial did for one hour 25.1 knots, and for the whole eight hours attained a mean of 24.8 knots. This is the mean reached by the *Drake* in her last year's record. This year the *Drake* has not made so much, 24.6 being the highest recorded.

In the eight-hours' passage trial at full power in the Second Cruiser Squadron the order was *Drake*, *Devonshire*, *Carnarvon* and *Antrim*. The *Drake* is the better steamer of these four ships by about two-thirds of a knot, being a 23-knotter against 22.33 of the others. The *Drake* did 24.3, the *Devonshire* 22.7, the other two *Devonshire*-class vessels about 22 knots.

Group of Dreadnoughts.—The Admiralty decision to build a group of *Dreadnoughts* rather than any special advance upon that type has been a good deal criticised in certain quarters, but nautically it is probably very sound. It is very doubtful whether the *Dreadnought* by herself would be any great acquisition to an ordinary fleet. Her speed would be useless among slower vessels except in exceptional circumstances, while the long range of her guns could not be greatly utilized without neutralizing the lesser ranging ships.

This being so, a squadron of *Dreadnoughts* became necessary directly the type ship proved successful. According to rumor, the solitary battleship of the 1908–1909 program will be a departure from the classical *Dreadnought* lines, and very possibly carry 13.5 guns. On the other hand, little advantage is gained from forcing the pace, and so far all nations seem contented with 12-inch or less.

Vanguard.—The keel of the *Vanguard*, a new *Dreadnought*, has been laid at the yard of Vickers, Sons & Maxim, Barrow-in-Furness. This battleship is sister ship to the *St. Vincent* and *Collingwood*, and includes all the improvements suggested by recent experiments. Her tonnage was originally 19,250, but this will be increased some hundreds of tons owing to there being several alterations in the plans since tenders were invited. She will be ten feet longer and two feet broader than the *Dreadnought*, and will be more

powerful. The builders have to deliver this battleship in two years, and she is expected to come off the stocks in November this year.

The Battleship Bellerophon.—Following the successful trials of the *Dreadnought*, three new vessels of the same type were laid down, and have now been launched. The *Bellerophon* was put into the water July 27 last from the Portsmouth dockyard; the *Temeraire* on August 23 from the dockyard at Devonport, and the *Superb* on November 7 at the Elswick yards, Newcastle-on-Tyne. These ships are somewhat larger than the *Dreadnought* in displacement, although of the same overall dimensions. They represent certain improvements over the earlier ship, prominent among which are an increase in the length of the 12-inch guns from 45 to 50 calibers, and the raising of the central turret so that its guns may be fired over the after turret, and thus increase the astern fire of the ship.

The displacement is 18,600 tons, as compared with 17,900 in the *Dreadnought*, the difference being due to an increased fullness in the form of the hull, and also to a slight increase in the draught. The weight of the hull and armor is stated to be 11,800 tons as compared with 11,100 in the case of the prototype. The launching weight of the *Bellerophon* was above 7,000 tons, and of the *Temeraire* 7,475 tons. The length is given as 490 feet between perpendiculars, with a beam of 82 feet and a draught of 26 feet 3 inches.

Propulsion is by means of four screws actuated by Parsons turbines, with a designed shaft horsepower of 23,000 and a designed speed of ship of 21 knots. With 900 tons of coal at normal draught, it is estimated that the radius of action at 12 knots would be 5,800 nautical miles. It is possible, however, to carry a total of 2,500 tons of coal and oil.

The main defensive armor consists of a belt with a maximum thickness amidships of 11 inches, decreased to 4 inches at the ends. The heavy guns are in turrets protected by 11-inch armor, while the two conning towers are armored with 11 inches (forward) and 8 inches (aft) of steel. The protect-

ive deck has a thickness on the slopes of $2\frac{3}{4}$ inches, decreased to $1\frac{3}{4}$ on the flat. Some protection has been given the ships in a cellular construction of the hull to avoid the disastrous effects which might be expected from a torpedo thrown by either a torpedo boat or a submarine vessel.

The main battery consists of ten 12-inch guns, 50 calibers long, and located in pairs in five turrets. Three of these turrets are on the center line, one being on the forecastle, one on the after deck, and one aft of amidships, and at such an elevation as to be able to fire over the turret on the after deck. The two remaining turrets are placed, one on either beam, somewhat forward of amidships, and it is said that they can direct their own fire throughout a semi-circumference, from straight ahead to straight astern. This gives a broadside of eight of these powerful weapons, a theoretical bow fire of six, and a theoretical astern fire of eight. The probable maximum bow and stern fire at sea, however, would be four and six guns, respectively. The secondary battery, which is intended for defense against the attack of torpedo vessels, consists of 4-inch guns in place of the 3-inch weapons on the *Dreadnought*. In addition, there are five submerged torpedo tubes for 18-inch torpedoes, one tube being right astern, while the others are on the broadside and bows.

The ship will be steered by two rudders, as in the case of the *Dreadnought*, and of the new battle cruisers of the *Inflexible* type, and it is said that steering gear of a new type is to be fitted. One of the many minor departures from the *Dreadnought* design is the placing of the tripod mast astern of the two funnels, instead of between the two as in the type ship. —"International Marine Engineering."

A Wonderful Floating Dock Yard.—The fitting out of His Majesty's ship *Cyclops* by Sir James Laing & Son, ship builders, Sunderland, has now been completed, and from particulars that can be obtained she is destined to be one of the most novel craft afloat. The secrets of this ship have been so jealously guarded that even the workmen of the builders have been conducted to the departments in which their work

lies, and have not been allowed to communicate with any other part of the ship. Even at meal times, if the workmen had brought their food with them they had to go ashore to eat it, all this in accordance with the carrying out of the official-secrets act. Nevertheless a few privileged persons have been allowed to see through the ship, and they all speak with wonder of what they have seen. The works on board the ship are equivalent to those of a dock yard employing 300 workmen, that being the number of artificers she will carry in addition to the crew to work the ship. H. M. S. *Cyclops* may be described as the most complete repair ship or floating dock yard in the world, and is the outcome of an experiment made some time ago when an old cruiser was converted into a repair ship at Portsmouth and named *Vulcan*. The *Cyclops* is a vessel of 11,000 tons and her dimensions are: Length, 460 feet; breadth, 55 feet; and depth, 40 feet. Ship-yard and engineering machinery are fitted up in her interior. As a matter of fact there is not a machine to be found in a ship yard or marine-engine works that is not represented in the hold of the *Cyclops*. On her lowest deck is a fully-equipped foundry and forge with cupolas where damaged parts of machinery can be replaced by new castings. Then there are carpenters', blacksmiths' and armorers' shops, fully equipped, fitting works, coppersmiths' and electricians' departments. On a higher deck is a boiler shop where boiler and ship plates can be dealt with, punching and shearing machines being there just as in a land ship yard. A powerful crane travels all around the ship to lift repairs from the holds, and on or off the warship that has come up for repairs. An electricity generating station is also included in the *Cyclops*' equipment, for by this power all the machines and cranes are worked. Ice-making plant is also carried, and as a contrast refrigerating is also represented, while on another deck is a gigantic set of condensers capable of supplying a whole fleet with fresh water. A few examples of the capabilities of the works on board may be given. If she is accompanying a fleet at sea and one of the ships loses a propeller, instead of being towed

home to a dock yard, the commander will simply signal to the *Cyclops* for a new propeller to be made and the order will be executed. The same applies to anchors, and in this connection it is amusing to see a huge anchor hanging over the bows of the *Cyclops* in correct position which on close examination proves to be made of wood. This is simply one of the complete sets of templets which the vessel carries for all sorts of castings required in the navy. In addition to having any portion of machinery renewed or repaired, vessels of the fleet, in case of the refrigerating plant breaking down, can be supplied with unlimited quantities of ice from the *Cyclops*, made on board, and in case of accidents to their condensing plant supply them with fresh water. The vessel has taken two years to fit out since she was launched. She has a speed of about 16 knots an hour, and she is believed to be the only specially-built craft of her kind in the world.—"Marine Review."

FRANCE.

Trials of French Battleships.—The four French battleships *Democratie*, *Justice*, *Liberté et Verité* which belong to the Naval Program of 1900 will shortly be added to the effective strength of the French navy. For the first time for a very long while France is about to have a fleet of similar vessels of large displacement. This is all the more remarkable because ever since sailing vessels went out it has been the custom to have a conglomeration of warships of different types to form the navy, or, as one of their own admirals has called it, a veritable "naval museum."

The four newest battleships differ from the *République* and the *Patrie* in the weight of their armament. In addition to their 305-mm. (say 12-inch) guns, these two latter vessels have only a comparatively feeble secondary armament. In consequence they could not compete on equal terms with similar vessels of other nations. In the four newer vessels the number of secondary guns has been decreased, but their caliber has been increased. Their armament consists of four 305-mm.

guns, arranged in pairs in turrets placed axially; six 194-mm. (7.76-inch) guns, in six turrets arranged hexagonally on the spar deck, three on each side; four guns of like caliber, and twenty-two 47-mm. (1.85-inch) quick-firers, which are undoubtedly of too light a character to repel the attack of modern destroyers.

As regards speed, as may be seen from the table following, the results achieved by the *Democratie* and *Justice* come very near those attained by the *République* and the *Patrie*.

The first thing which strikes one on reaching the bridge of one of these battleships is the absence of the encumbrances which it has been customary to find on all the vessels built previously to the 1900 program. The decks, both fore and aft, have been kept wonderfully free, and this permits of an unrestricted use of the 305-mm. guns, and as well as of those of 194-mm. bore. It is, however, to be noticed that boat stagings are placed directly above certain turrets, and it is pretty certain that after one or two shots all this ironwork would be wrecked, and by falling down put the guns out of action. On getting below decks it is also striking not to find the hamper which is so commonly met with in French warships. As a matter of fact there are unusual facilities for getting about and for carrying out maneuvers. The transverse armored bulkheads, however, are only provided with two openings, one at each side, and these openings only permit of the passage of one man at a time.

The conning tower is of large size in the vessels of this type. There is a good view of the horizon, but sufficient precautions do not appear to have been taken to prevent splinters entering the windows. The approach to the tower seems to be better protected than in other types.

The armored tubes which protect the bases of the turrets of the 194-mm. guns and serve for raising the ammunition from the upper armored deck to the spar deck, do not appear to be sufficiently strong to withstand the attack of an enemy, who could easily hit them, as they are not behind any protective armoring. The funnels, too, have no protection between

decks, and if a well-directed shot traversing the spar deck were to wreck one of the funnels life would be impossible in a not inconsiderable part of the ship, while, of course, the evaporative power of the boilers would be reduced, and, as a consequence, the speed of the vessel also. It is difficult to understand why such important parts should have been left unprotected in this manner.

The quarters of the admiral and commandant, which are placed aft, are luxuriously arranged, but are decorated with very inflammable materials. The metal bulkheads are covered with pitch pine 2 cm. thick, which has not been made non-inflammable, and which is covered with embossed linoleum. This combination would be excellent for feeding a conflagration, and as the quarters are not protected with armor, they could easily be set alight by the enemies' fire. Moreover, in the various apartments there is a much larger quantity of woodwork in the furniture, fittings, &c., than is met with in similar British or German vessels. These quarters are situated just aft of the aft 305-gun turret, and if a fire were to occur in them it would greatly hinder the manipulation of the guns in this turret.

Coming now to mechanical arrangements, there is, apparently, much to be desired. First of all, there is the rudder, which is only worked electrically. This is provided with a mass of controlling apparatus, registers, &c., which will give an angle to half a degree, perhaps, and which will work at three speeds; but, apparently, the least little thing puts all the arrangements out of gear, and the system is so thoroughly complicated that it takes a long time to put it ship-shape again. Nothing may, of course, go wrong in times of peace, but serious trouble might arise if anything happened to the rudder-controlling mechanism while the vessel was in action; and this part of the equipment has been severely criticised by some French naval experts.

The three main engines are in one compartment in the center portion of the vessel, and space has had to be so much economized that it is difficult for a man to get round and

between them. Consequently, supervision, oiling, upkeep, and, much more, repairs or the replacing of any part, can only be carried out with considerable difficulty. Further than this, in order to take the fullest advantage of the latest developments in machinery, a whole host of controlling and regulating devices, of counters and registering arrangements, has been provided, which, though they may permit of easier navigation during maneuvers, and of brilliant evolutions, render the working of the machinery all the more difficult when the vessel is in action, and, it is thought, might consequently cause her to be totally lost. The descent to the engine room is typical. It is by means of a single ladder, which only allows of the passage of one man at a time, and in case of accident, whether during trials or during maneuvers, it would be impossible to aid quickly those who might be down below. In spite of these defects, to which we may say our attention has been called by one having a large knowledge of French warships, two out of the four of these vessels —that is to say, the *Democratie* and the *Justice*, which are the first of the four to undergo their trials—have done some excellent work as regards speed, as will be seen from the table compiled from data of their official trials.

The speed of *La Justice* under natural draft with all boilers at work during her twenty-four hours' trial was only six hundredths of a knot below the contract speed with forced draft, which is undoubtedly a remarkable performance.

The battleship *Liberté* has also recently concluded her acceptance trials. In these a comparison was made between her and the battleship *La Justice*. The members of a commission which had been appointed to carry out the trials first of all went on board *La Justice* at Toulon to make a three-hours' forced-draft trial, with only three-quarters of the boilers under steam. Eighteen thousand five hundred indicated horsepower was easily maintained, though it will be remembered that the contract requirements were only 17,500. The coal consumption during this trial worked out at 860 grammes, which is equal to 1.895 pounds per horsepower hour. On their return

OFFICIAL TRIALS OF THE BATTLESHIPS *LA DEMOCRATIE* AND *LA JUSTICE*.

	Contract requirements.	Results obtained with *La Democratie*.	Results obtained with *La Justice*.
Three Hours' Trial with all Boilers and Forced Draft.			
Type of boiler	...	Belleville	Niclausse
Number of boilers under steam	...	22	24
Grate area at work, sq. m	...	124	128
Indicated horsepower	17,500	19,190	18,848
Consumption of coal per I.H.P., kg	...	...	0.827
Consumption of coal per sq. m. of grate area, kg	120	120	117
Average speed, knots	18	19.44	19.43
Twenty-four Hours' Trial with all Boilers and Natural Draft.			
Number of boilers under steam	...	22	24
Grate area at work, sq. m	...	124	128
Indicated horsepower	10,500	11,472	11,630
Consumption of coal per I.H.P., kg	0.80	0.673	0.693
Consumption of coal per sq. m. of grate area, kg	...	...	73
Average speed, knots	...	17.39	17.94
Consumption Trial at Low Speed.			
Grate area at work, sq. m	...	26.25	25.82
Indicated horsepower	2,200	2,584	2,541
Consumption of coal per I.H.P., kg	0.600	0.586	...
Consumption of coal per sq. m. of grate area, kg	...	...	75
Average speed, knots	...	7.5	7.8

to Toulon the Commissioners went on board *La Liberté* for a four-days' cruise. First of all there was a 62-hours' trial, with all the boilers at work under natural draft. A speed of 17 knots was maintained without difficulty. Following this was to have been a 24-hours' run with only twelve boilers under steam, burning 120 kilos per square meter of grate area, which is equivalent to 24.57 pounds per square foot. This run was satisfactorily commenced, but the vessel encountered such extremely severe weather in the Gulf of Lyons that the speed had to be reduced, as the stoking could not be carried on in such a manner as to maintain the required coal

consumption, which, as a fact, fell off to 80 kilos per square meter. Under these conditions the vessel returned to Toulon without any accident or incident. The return journey occupied 28 hours.

The following table gives the results of the official trials of the *Liberté*.

OFFICIAL TRIALS OF THE BATTLESHIP *LA LIBERTÉ*.

	Contract requirements.	Results of the trials.
Trial with All Boilers at Work under Forced Draft.		
Type of boilers	Belleville	
Number of boilers under steam	22	22
Power developed, I.H.P.	17,500.0	20,563.0
Consumption of coal per sq. m. of grate area, kg.,	120.0	117.0
Average speed, knots	17.0	19.31
Twenty-four Hours' Trial with All Boilers at Work Under Natural Draft.		
Number of boilers under steam	22	22
Power developed, I.H.P.	10,500.0	11,624.0
Consumption of coal per H.P. hour, kg	0.750	0.634
Average speed, knots	...	17.37
Consumption Trial at Low Speed.		
Number of boilers under steam	5	5
Consumption of coal per H.P. hour allowed, kg	0.700	...
Actual consumption per H.P. hour, kg	...	0.604

Number of engines, 3.

Diameters of cylinders, 860 mm. (33.86 inches), 1,250 mm. (49.21 inches), and two of 1,400 mm. (55.1 inches).

Stroke of all pistons, 1,130 mm. (44.49 inches).

Pressure of steam at stop valves, 16 kilos. per sq. cm. = about 227.5 pounds per square inch.

All the vessels which have been built since February, 1903, have to make their full-power trials in the following manner: A trial of ten hours' duration, with all the boilers under steam and with forced draft. Then a trial of three hours' duration, with only three-quarters of the boilers under steam. Under these circumstances the speed is to be the same as in the first trial. This arrangement is intended to imitate war condi-

tions, in which 25 per cent. of the boilers may be put out of action. The first large vessel to be tested under this new rule on coming from the hands of her constructors will be the *Ernest Renan*, of 36,000 indicated horsepower, which will probably undergo her trials at the end of May, this year.—"The Engineer."

GERMANY.

Trials of the German Battleship Pommern.—This ship, which was launched in December, 1905, is one of the *Deutschland* type, with a displacement of 13,000 tons, and designed for a speed of 18 knots, with 16,000 horsepower applied to three screws. The length between perpendiculars is 398 feet 6 inches, with a beam of 72 feet 10 inches, and a draught of 25 feet. Provision is made for the carrying of 700 tons of coal at a normal displacement, which may be increased to 1,600 tons with bunkers full, besides which 200 tons of oil may be carried.

The military features include a battery of four 40-caliber 11-inch guns mounted in pairs in turrets on the center line, forward and aft; fourtern 40-caliber 6.7-inch rapid-firing guns; twenty-two 3.4-inch guns; fourteen 1-pounders; four machine guns, and six submerged torpedo tubes. The armor belt has a maximum thickness at the waterline of 9.45 inches, decreased to 3.94 inches at bow and stern. The heavy guns are protected by 11 inches of armor, and the lighter primary guns by armor from 5.9 to 7.87 inches in thickness.

In a 6-hour forced-draft trial September 13 a speed of about nineteen knots was obtained, the horsepower being 18,697, with 118 revolutions per minute, an air pressure of 0.9 inch, and a coal consumption per indicated horsepower per hour of 1.61 pounds. The next day a maximum speed of 19.26 knots was reached at 122.8 revolutions per minute, and 20,348 horsepower (Admiralty coefficient 194). On September 17 a 24-hour trial was run, in which the center screw was allowed to run idle, propulsion being by means of the two side screws. With 3,464 horsepower the speed was 10.88

knots (Admiralty coefficient 205.5), while the coal consumption was 1.59 pounds per horsepower-hour.—"International Marine Engineering."

The Ersatz Baiern will be launched in February at Wilhelmshaven. She will be pushed on at record speed in order to test the design. Some special interest attaches to this ship on account of the vigorous denials of her being built made by some of our contemporaries seeking excuses for our reduced naval shipbuilding program. The slip at Wilhelmshaven was destroyed last spring, so that she could not be laid down, and right on into the summer she was not laid down. Quite a number of people began to regard her as a myth. She appears, however, to be a very solid one.

She will probably be ready for her trials at the end of this year, with the acceleration of building. In any case she will be to all intents and purposes ready for sea by March, 1909, the date always stated in Germany for her completion. So the delays caused to the German program by the *Dreadnought* do not seem to be over and above serious.

German estimates for 1908 provide for nine new battleships, of which two are of 13,000 tons each, and are practically ready; four armored cruisers, two of which are practically complete; six small cruisers, twenty-four destroyers and seven submarines. Seven battleships are now under construction, or to be laid down in 1908. They belong to the *Dreadnought* type, with a displacement of at least 18,500 tons each. Taking a new Navy Bill as a basis for calculation, Germany at the end of 1914 will have afloat sixteen new battleships of the *Dreadnought* type and five cruisers of the *Invincible* type, supported by ten battleships of 13,200 tons, none of them over twelve years old, and two armored cruisers, of 11,600 tons, just eight years old.

Submarines.—The construction of submarine boats has recently been taken up by German shipbuilders, and, after a series of trials on a small model boat, the Germania shipyard at Kiel have just completed a large submarine of 240 tons. The main dimensions of this vessel are: Length over all,

137.5 feet; maximum width across frames, 11.7 feet; draught of boat when emerged, 7.8 feet. An electric motor and gas engine, each with an output of 200 I.H.P., are fitted to each of the two propeller shafts, the propeller being adjusted from the inside of the vessel. The electric motors are designed for propulsion below water, and receive current from an accumulator battery installed amidships. The battery is sufficient to drive the boat below water for fully three hours at its maximum speed of 9 knots. When on the surface the gas engines are preferably to be used. The fuel is carried in tanks, arranged outside of the boat (according to patents of the Germania shipyards) thus guarding against explosion. The store carried by the submarine enables the latter to cover a distance of 1,000 knots at her maximum speed of 11 knots on the surface.

The motors can obviously be used also for propulsion above water, while both types of motor can also be used simultaneously for the propulsion of the vessel.

The submersion and emersion of the boat is effected by filling and discharging the ballast tanks arranged inside, as well as by the aid of two pairs of horizontal rudders. The maximum admissible depth of submersion has been fixed at about 120 feet. Only five minutes are required to prepare for submerging the boat.

Special care has been bestowed on ventilation, which is secured by an electrically-operated ventilator, which, as long as the boat is above water, will constantly supply all the rooms with fresh air. When submerged, the vitiated air is passed through a cleaning tank, after which it returns towards the various compartments of the boat. With a crew of 10 men, the vessel is able to move under water for periods up to 24 hours.

The armored conning tower arranged in the center of the boat and enclosing all necessary instruments, such as viewing apparatus, manometers, rudders and telephones, is large enough readily to accommodate the commander and the pilot. Two periscopes have been provided, which, both in a vertical

and horizontal direction, cover a field of 50 degrees. The length of these inclosing telescopic tubes has been chosen with a view to allow the boat to travel at a depth sufficient to warrant it against gun fire, while still enabling it to cover the whole of the horizon.

The armament of the submarine comprises an 18-inch bow torpedo-launching tube. One of the three large-sized torpedoes carried by the vessel is contained in the tube, while the two remaining ones are arranged in watertight reservoirs.

Trial runs performed in Eckernförde Bay, both in the emerged and submerged condition, have demonstrated the satisfactory sea-going qualities of the submarine.—"Scientific American."

The launching of the Nassau.—The first of the great German all-big-gun ships, the *Nassau*, was successfully launched March 7, 1908, at the Imperial Dockyard at Wilhelmshaven. Not only in armament, but in arrangement of turrets and guns, the *Nassau* is to be the most powerful ship that has yet taken the water in any part of the world. The German government is maintaining the greatest secrecy on this point, but there is now not the least doubt—unless reliable sources of information are entirely misinformed—that the *Nassau* will have a stronger all-big-gun battery than either the improved British *Dreadnoughts* of the *St. Vincent* class, the French *Dantons*, the American *Delawares*, the Japanese *Akis*, or even the proposed Italian ironclads.

American naval students will, perhaps, find some difficulty in identifying the *Nassau* in their "Brassey" or "Jane," or even in the official German Navy List. It is the *Ersatz Bayern*, about which so much has been said and written. *Ersatz Bayern* was not intended as the name of the ship when those two words were incorporated into the Navy List. Perhaps the nearest English equivalent for the German word "Ersatz" is "substitute." *Ersatz Bayern* merely means "Substitute for the *Bayern*." Germany has a continuous building policy. Until the adoption of the present Naval Estimates, the age limit of German battleships was twenty-five years. This has

been reduced to twenty years. Every time a German battleship attains that age another is to be laid down in her place. There is already an old *Bayern*, and the *Nassau* is the ship that takes the place of this obsolete vessel. Until a name had been chosen for the substitute for the *Bayern* this new vessel had to be designated some way in official naval nomenclature, and *Ersatz Bayern* was regarded as a better temporary method of identification than the use of "A" or "B" in speaking of the ship. But, as soon as the new vessel was officially christened she shook off her old designation, and from now on she will be known as the *Nassau*. What are now denominated as the *Ersatz Sachsen*, the *Ersatz Baden* and the *Ersatz Wurtemburg*, which are to supplant the old *Sachsen*, *Baden* and *Wurtemburg*, will also receive other names when christened.

The *Nassau* was christened by the Grand Duchess of Baden, in the presence of a great gathering of officials, headed by the Emperor, Prince Henry of Prussia, Prince Rupprecht of Bavaria and Prince Henry of the Netherlands. The keel of the *Nassau* was laid in July, 1906, and she is the pioneer of the four ships of this class, representing the Fatherland's reply to the British *Dreadnought*. The building of the *Nassau* has taken considerably longer than usual. This fact is attributable partly to the burning of the building slip at Wilhelmshaven, but principally to the entirely novel design. Moreover, when the vessel left the stocks she was in a very advanced condition, and it is expected that the summer of 1909 will see her in commission. The work will be pushed rapidly, and she will be ready substantially at the date when Germany first contemplated having this vessel take the sea, in spite of the vigorous denials that were for a long while made as to the actual construction of the ship.

Nothing but steel has been used in the construction of the *Nassau*. The reciprocating engines are in three sections, and there are triple screws. A speed of 19 knots is hoped for by the Government. Her armor will be extraordinarily complete, and it is a noticeable fact that the belt, 12 inches thick

amidships, will extend five or six feet clear above the water-line. From this it would appear that the German Admiralty has not been oblivious to the lessons of the conflict in the Far East, which clearly demonstrated the danger of a belt submerged at anything over normal displacement.

Reams have been written and all sorts of theories advanced in respect to the probable armament of the *Nassau*, but it is now practically certain that she will carry sixteen 11-inch guns of 50 caliber besides a large number of rapid-fire weapons for repelling torpedo attack. It is understood that the main battery will be arranged in eight double turrets, one forward and one aft, each flanked to port and starboard by two others, the remaining two turrets being placed amidships on an axial line with those at the bow and stern. This disposition will allow of twelve guns being brought to bear on either broadside, and six ahead or astern.

It is quite possible, however, that a heavier stern fire may be realized by elevating one of the turrets amidships, so as to enable its two guns to fire over the stern turret and thus bringing eight guns to bear.

An alternative arrangement has been mentioned, whereby the two middle turrets would be placed to port and starboard respectively, but farther from the axial line than the forward flanking turrets. This would mean a broadside fire of only ten guns, though ten could be brought into action ahead and ten astern. The adoption of the first arrangement is, however, almost certain.

The total cost of the *Nassau* is approximated at $9,187,-500. Of this $5,568,000 goes for the actual construction, armor and equipment; $3,375,000 for the guns; and $247,-000 for the torpedo armament. In this sum are included the expenses which will be incurred in connection with the trial trips. The battleship will carry eight hundred and sixty men, or one hundred and thirty more than any previous German warship, and there will be twenty-seven executive and engineer officers. The *Nassau* having now been launched, the building slip will be immediately prepared for one of the

battleships of this year's program—the *Ersatz Oldenburg*, the *Ersatz Siegfried* or the *Ersatz Beowulf*.

The huge armored cruiser designated "*E*," in course of construction at the Keil Imperial Dockyard, will take the water on April 11. Originally set for the end of March, the launching has been postponed until the former date, owing to delay in the delivery of several large castings. Very few details of an authentic character are known about this vessel, but it is believed that she will embody most of the essential details of the British *Invincible* type except that her armament will consist of twelve 11-inch guns. A speed of 25 knots an hour is projected, and turbines have been mentioned in connection with this cruiser; but in view of the German Government's known coyness in regard to this method of propulsion, it is likely that reciprocating machinery will be installed.

It is instructive to note that the recent speed trials of the new German warships have shown a considerable increase over the contract speeds. The battleship *Pommern*, 13,040 tons, over a measured mile reached a speed of 19.21 knots, whereas the contract speed was 18 knots an hour. The turbine protected cruiser *Stettin* has also exceeded her contract speed; while the armored cruiser *Gneisenau* did 23.8 knots on her trial trip, an increase of 1.3 knots over the contract.

The armored cruiser *Scharnhorst*, which ran ashore near Keil on January 16, while engaged in target practice, left the dockyard hands again a fortnight ago, apparently in as good condition as originally. The repairs have been executed with commendable promptitude, having extended over barely five weeks, which, in view of the serious damage she sustained, —a hole 90 feet long was torn in the hull,—is something of a record Pessimistic reports circulated in the national and, foreign press after the accident, and it was generally believed that the cruiser would be off the active list for at least a year. —"The Navy."

GREECE.

Torpedo-boat Destroyer for the Greek Navy.—The last of the four torpedo-boat destroyers built for the Royal Hellenic Government by Messrs. Yarrow & Co., Limited, of Poplar and Glasgow, has now completed her trials, and will be handed over very shortly to the representatives of the Government. These vessels are of the following dimensions: Length, 220 feet; breadth, 20½ feet; depth amidships, 12 feet 4 inches; displacement, 350 tons; indicated horsepower, 6,000. Contract speed, 31 knots, when carrying a load of 60 tons. The main machinery consists of two sets of four-cylinder triple-expansion engines, driving two shafts, steam being supplied by four Yarrow straight-tube boilers.

The hull is built throughout of high-tensile steel. The armament consists of two 76-millimeter and four 57-millimeter Hotchkiss quick-firing guns and two torpedo tubes. It is worthy of note that when these vessels were proposed, no vessel of a similar type and displacement was armed with such heavy artillery.

The bridge and platforms extend from the conning tower to well abaft the foremost boiler-room bulkhead, the uptake from the forward boiler being carried horizontally for some distance to enable this to be done. It is most important, as all navigators know, for the steering position to be as far removed from the bow as possible, and by means of the device adopted by Messrs. Yarrow & Co. of conducting the gases from the forward boiler for a certain distance in a horizontal direction before joining the funnel, this can be carried out.

There are four ammunition hoists by Megy for the rapid supply of ammunition to the guns, these hoists being in direct communication with the magazines and shell rooms by means of trunks to the upper deck, that for the forward 76-millimeter gun being continued to the height of the gun platform. Valves are fitted to the ship's side below water to admit of rapidly flooding the magazines and shell rooms in case of fire.

Efficient means for rapidly changing the air in the maga-

zines is provided by an installation of Sturtevant electrically-driven fans, each of which is capable of dealing with about 250 cubic meters of air per hour.

In the last two vessels provision is made for five separate cabins for the officers, four of these opening out of the ward-room.

Each vessel has a complete installation for electric lighting, the whole of the navigating instruments being electrically illuminated. A searchlight projector is also fitted abaft the bridge, and the crew spaces and officers' apartments are very efficiently ventilated by means of electric fans fitted in mushroom ventilators.

The speed obtained on the full-power trials of the *Lonki*, one of the vessels, with a load of 60 tons, was 32.535 knots, during a continuous run of three hours duration, the radius of action at a speed of 14 knots being about 3,970 miles. Progressive trials were carried out to determine the speeds obtainable under deep-load conditions, the displacement varying from 405 tons to 387 tons, the load varying from 119 tons to 101.5 tons. We understand that the results of the whole of these trials have given the greatest satisfaction to the Greek authorities.

The construction of these vessels has been under the superintendence of Captain Hepites, the Chief of the Greek Naval Commission, and Mr. Leondopoulos, resident inspector, and to these gentlemen a great deal of the credit is due for the success of these four destroyers. The names of the vessels are *Thyella*, *Nafkratoussa*, *Lonki* and *Sfendoni*, which names, when translated into English, mean *Squall*, *Champion*, *Spear* and *Sling*.

Considering the speed obtained with these Greek destroyers, and that each vessel cost about one-third of the recently-constructed 33-knot destroyers for the British government, many naval authorities are of opinion that the small additional speed obtained in the latter type is not worth the enormous additional cost.

ITALY.

Italian Armored Cruiser Pisa.—On September 15 there was successfully launched from the shipyard of Orlando Brothers & Company, Livorno, Italy, the first of four first-class armored cruisers building for the Italian navy. The ship has the following dimensions:

	Meters.	Feet.
Length over all	140.5	461
between perpendiculars	130.	427
Extreme beam	21.06	69
Depth	12.15	39.9
Mean draught	7.18	23.6
Maximum draught	7.43	24.4
Metacentric height	1.2	3.94
Normal displacement, in tons		10,118

This ship is propelled by twin screws actuated by triple-expansion engines, with a designed horsepower of 19,000 under forced draft and at 132 revolutions per minute. This is expected to give a speed of 22.5 knots, with a corresponding speed of 20 knots at 15,200 horsepower and natural draft. Steam is supplied by twenty-two water-tube boilers of the Belleville type, fitted with economizers.

There is a complete armor belt running from stem to stern, with a width of 7 feet 3 inches, of which 4 feet 11 inches is below the waterline. The maximum thickness is 7.87 inches, decreased to 3.16 inches at stem and stern. The protective deck has a thickness of 1 inch.

The battery is an extremely powerful one, including four 10-inch guns, 45 calibers long, mounted in pairs in turrets forward and aft, with an arc of fire of 260 degrees, half each side of the center line. The height of these muzzles above the water plane is 24 feet 3 inches. There are eight 7.5-inch guns, 45 calibers long, in pairs in four turrets at the corners of the superstructure. These have an altitude above the water of 22 feet 2 inches. They have a range of fire of 160 degrees, of which 90 degrees comprehends the arc between the fore-and-aft line and the beam for the various guns. The secondary battery includes sixteen 3-inch guns, eight 3-

pounders and four Maxims. There are three 18-inch torpedo tubes, all submerged, two being located just aft of the ram, while the other one is just above the rudder. All of the artillery is of the latest Vickers type, and was made in Barrow-in-Furness.

These ships are such an advance over anything else of the same size and type yet laid down that a comparison with some of the efforts of other powers will doubtless be interesting. With this idea in view we will compare them with the *Charleston* class of the United States navy, the *Cornwall* class of the British navy, the *Tokiwa* class of the Japanese navy and the *Marseillaise* class of the French navy. These ships are all near enough of a size to make a comparison worth while.

	Pisa.	*Charleston.*	*Cornwall.*	*Tokiwa.*	*Marseillaise.*
Displacement, in tons	10,118	9,700	9,800	9,750	9,856
Horsepower	19,000	27,200	22,700	20,550	21,800
Speed, in knots	22.5	22.04	23.69	23.09	21.64
Admiralty constant	281	179	268	274	214
Main battery, inches	Four 10 Eight 7.5	Fourteen 6	Fourteen 6	Four 8 Fourteen 6	Two 7.6 Eight 6.4 Six 3.9
Broadside, in pounds	2,800	800	900	1,700	822

The splendid propulsive results achieved with the *Cornwall* and *Tokiwa* will in all probability be equaled or surpassed by the *Pisa*, such is the extremely high character of Italian design from this point of view. In comparison, the *Charleston's* performance is truly pitiable, and her broadside is the weakest of the five, being less than 30 per cent. as powerful as that of the *Pisa*, and at long ranges much less even than that small percentage.

JAPAN.

Mikasa.—According to a recent photograph of the *Mikasa*—or what purports to be a recent photograph—this ship remains exactly as she did at Tsushima. The photograph is certainly fairly recent, as no guns are on board, so it was taken after her salvage. The upper-deck 6-inch casemates remain as before—turrets to carry 10-inch guns are conspicuous by their absence, and we begin to suspect more than ever that the four 10-inch

added to her armament was a proposal rather than much else. We do not see how the extra weight could be managed. If it be attempted, we fancy that it will be no more successful than our increase of armament to the *Centurions*. These ships were never very fit for fighting, but they steamed splendidly. After reconstructions they were still unfit for modern battle, and also unable to steam. No reconstruction involving additional weights has ever succeeded yet, nor is any ever likely to. The original designer, we may be sure, put into armor and armament all the weight that he could. Since then guns and armor may have improved much, and ways of building ships to carry a greater percentage of these things may have been elaborated, but a ton still weighs a ton. The talented but much-criticised gentlemen who design battleships may not always hit upon an absolute best, but they certainly do not leave neglected chances to carry several hundred tons extra. Had the *Mikasa* been safely able to carry the weight of four extra 10-inch guns and mountings and armor—a trifle of from anything between 500 and 1,000 tons—she would have steamed out of Vickers, Maxim's yard with that weight used up to the last ounce.

RUSSIA.

Admiral Makaroff.—The Russian armored cruiser *Admiral Makaroff*, built by the Forges et Chantiers de la Mediterranée at La Seyne, Toulon, made 22.55 knots on her full-power trials—that is, 1.55 knots over the contract speed. She is a sister to the famous *Bayan* and differs from her only in having a solitary mast, placed between the funnels. A single mast is the regulation for all Russian armored cruisers now. Both the *Rossia* and the *Gromoboi*, which used to have three, are now reduced to a solitary mast.

Russia's Naval Losses.—The Russian navy lost in the recent war with Japan a total of fifty-six vessels, with a gross displacement of 249,000 tons, to which must be added auxiliary vessels, with a displacement of 21,000 tons. The addi-

tion of ships ready and building up to January 1 represents 145,000 tons, and the number of vessels 159. Of these 109 are torpedo craft, displacing 35,650 tons, 69 of them destroyers and sea-going torpedo boats, 10 of them small boats and 30 submarine boats. In addition are gunboats, mining vessels, auxiliary vessels, to the number of 36. The present strength of the Russian navy gives a total displacement for battleships of 161,000 tons; for cruisers, 126,000 tons; for torpedo craft, 54,000 tons; and for special, old and auxiliary ships, 253,000 tons. For the manning of the ships 57,000 men will be required, but the present strength is 47,000.

TURKEY.

New Coast-Guard Boats for Turkey.—A scout and five gunboats for the Turkish government have recently been completed at the Chantiers de la Loire. These steamers are designed for coast-guard work, and for the suppression of piracy and smuggling and the settlement of various disputes along the Turkish Coast in the Red Sea and the Persian Gulf. The scout has been named *Marmaris*, while the first of the gunboats has been called *Seddlibaschir*. These two types of vessels are quite different from each other and are not at all in line with present up-to-date practice of the larger naval powers. For their own purpose, however, they will doubtless prove satisfactory.

The *Marmaris* has an armament including four 9-pounder and two 1-pounder guns and one 18-inch torpedo tube. She has a crew of twelve officers and fifty-four men. The gunboats are arranged for three 3-pounder and two 1-pounder guns with one torpedo tube, and are manned by nine officers and thirty-eight men.

The general dimensions of the two types are as follows:

	Marmaris.	Gunboat.
Total length, feet	172	154
Extreme beam, feet and inches	24–07	...
Depth, feet and inches	13–09	11
Draught, feet and inches	11–10	7–11
Displacement, in tons	422	309

	Marmaris.	Gunboat.
Indicated horsepower	950	480
Speed, in knots	14.81	12.45
Radius of action, miles	2,000	1,200
Steam pressure, pounds	199	199
Scotch boilers	2	1
Sail area, in square feet	5,160	2,205

MISCELLANEOUS.

Trials of Lightship Number 88.—This ship has a length over all of 135 feet 9 inches, a length on the waterline of 112 feet 11 inches, a molded beam of 27 feet and a mean draught on trial of 12 feet 1 inch. The trial took place in the Delaware river November 22, 1907, and the displacement (fresh water) was 576 tons. The block coefficient was 0.572, and the wetted surface 4,749 square feet.

There is one compound engine, driving a solid four-bladed propeller. The engine has cylinders 16 and 31 inches in diameter, with a stroke of 24 inches, cutting off in the high-pressure at 66 per cent. The diameter of piston rod is 3½ inches. The cooling area of the surface condenser is 1,160 square feet. The propeller has a diameter of 7 feet 9 inches, a pitch of 10 feet and a pitch ratio of 1.29. The developed area is 2,328 square inches and the projected area 1,840 square inches. The ratio of projected to disk area is 0.271.

Steam is furnished by two boilers exhausting into a single stack 4 feet in diameter and 45 feet high above the grate. These boilers are of the gunboat type, working under natural draft, and have a diameter of 9 feet 3 inches and a length of 16 feet 3⅜ inches. The working pressure is 100 pounds per square inch. The total heating surface is 2,874 square feet, with a grate area of 73.2 square feet, giving a ratio of 39.26 to 1.

Two sets of runs were made, one set being over the measured mile (5,280 feet), while the other was a 6-hour continuous trial at full power. The measured-mile trials consisted of three runs in each direction, in order to determine the revolutions required for a speed of 10 knots. The mean of all the runs showed a speed of 9.98 knots with 125.7 revolutions per

minute, and a slip of 19.2 per cent. During the 6-hour trial the maximum horsepower observed was 394, the mean having been 320 horsepower, 119.9 revolutions per minute and a vacuum of 26.66 inches. The mean steam pressure in the boilers was 98.6 pounds per square inch.

	High-Pressure.				Low-Pressure.		
Standardization Run.	Top.		Bottom.		Top.		Bottom.
R.P.M.	...	...	...	126	...	...	...
Vacuum	...	...	...	26.5	...	...	...
I.H.P.	...	...	...	360	...	...	...
I.H.P.	...	206	...	...	...	154	...
Steam pressure	...	97	...	...	...	*6.25	...
Mean effective pressure	71.24	...	66.28	...	13.29	...	13.68
Mean reduced pressure	...	...	...	31.42	...	...	...
Six-Hour Trial.							
R.P.M.	...	...	...	126.5	...	...	...
Vacuum	...	...	...	26.7	...	...	...
I.H.P.	...	...	...	359	...	...	...
I.H.P.	...	204	...	...	...	165	...
Steam pressure	...	96	...	...	...	*6.25	...
Mean effective pressure	69.42	...	66.11	...	13.67	...	13.36
Mean reduced pressure	...	...	...	31.21	...	...	...
Linked Up ¾.							
R.P.M.	...	...	...	122.5	...	...	...
Vacuum	...	...	...	26.8	...	...	...
I.H.P.	...	...	...	329	...	...	...
I.H.P.	...	193	...	...	...	136	..
Steam pressure	...	95	...	...	...	*4	...
Mean effective pressure	68.12	...	64.3	...	12.62	...	11.89
Mean reduced pressure	...	...	...	29.55	...	...	...
Linked Up ½.							
R.P.M.	...	...	...	118	...	...	...
Vacuum	...	...	...	26.8	...	...	...
I.H.P.	...	...	...	298	..	...	...
I.H.P.	...	175	...	...	...	123	...
Steam pressure	...	97	...	...	...	*2	...
Mean effective pressure	62.28	...	59.5	...	11.81	...	11.12
Mean reduced pressure	...	...	...	27.77	...	...	...

Observations of the auxiliary machinery showed a mean revolution per minute for the circulating pump of 196; for the air pump, 33; for the feed pump, 18.6. The temperature

* Receiver pressure.

on deck was 55 degrees F., with the following observed temperatures below: Engine room, 80; injection water, 41.9; outboard discharge, 86.6; hotwell, 102.6; feed heater, 158 degrees. The indicator springs used were in all cases 60 pounds per inch for high pressure and 20 pounds for low pressure.

MERCHANT SHIPS.

A Mammoth New Atlantic Liner.—There is under construction in the Belfast yard of Harland & Wolff an immense passenger steamer for the Hamburg-American Line which has many points of interest entirely aside from its size. A principal feature is the fact that this ship is to be fitted with a combination of reciprocating and turbine machinery, there being provided three screws, of which the two outer ones are actuated each by a quadruple-expansion steam engine, while the center shaft is turned by a low-pressure steam turbine, the steam for which is given by the exhaust from the piston engines. The total horsepower will be somewhere in the neighborhood of 30,000, giving an estimated sea speed of 20 knots. It is reported that a swimming tank, 25 by 75 feet, and a tennis court are to be provided.

The principal dimensions of this ship show a length over all of 804 feet, a length between perpendiculars of 758 feet, a beam of 88 feet, and a depth to the upper deck of 63 feet 9 inches. It will be noted that the length over all exceeds that of the *Lusitania* and *Mauretania* by about 15 feet; the length between perpendiculars is 2 feet short of the Cunarders; the beam is the same, and the depth is more than 3 feet greater. The ship has thirteen watertight bulkheads and five complete decks in the hull, running from bow to stern.

Some of the principal scantling members have been given as follows by Schiffbau:

Flat keel, $1\frac{1}{4}$ inches; garboard strake, $1\frac{1}{16}$ inches; bottom strakes, $\frac{15}{16}$ inch; bilge strakes, 1 inch, 1 inch and $1\frac{1}{16}$ inches; side plates, $\frac{15}{16}$ inch; sheer strake, 1 inch; center-line vertical keel, $\frac{15}{16}$ inch; double-bottom horizontal center plate, $\frac{11}{16}$ inch; double-bottom side plates, $\frac{9}{16}$ inch; upper-deck stringer

plate, $\frac{15}{16}$ inch; inner stringer plate, $\frac{3}{4}$ inch; middle-deck stringer plate, $\frac{3}{4}$ inch; other stringer plates, $\frac{9}{16}$ inch; deck plating on the upper deck, $\frac{9}{16}$ inch; on the middle deck, $\frac{7}{16}$ inch; on the other decks, $\frac{3}{8}$ inch. The depth of the double bottom is given as 5 feet 4 inches, and the frame spacing as 36 inches. The frames are channels measuring 10 by 4 by 4 by $\frac{21}{32}$ inches. The deck beams on the upper deck are channels 8 by 4 by 4 by $\frac{1}{2}$ inches. The deck beams on the middle, lower and orlop decks are channels 10 by $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ inches. Hold beams measure 10 by 4 by 4 by $\frac{1}{2}$ inches.

The Cunard Steamship Mauretania.—Our description of the *Lusitania* will apply almost equally well to her sister ship. The difference between the two ships from a fundamental point of view is slight, but a number of minor differences, and particularly differences in the decorations, have been made. The present ship was built by Swan, Hunter & Wigham Richardson, Limited, Newcastle-on-Tyne, and has been supplied with propelling machinery by the Wallsend Slipway & Engineering Company, Limited. The general dimensions are as follows: Length over all, 790 feet; length between perpendiculars, 760 feet; breadth, molded, 88 feet; depth, molded, 60 feet 6 inches; gross tonnage, 33,200; mean load draught, 33 feet 6 inches; corresponding displacement, in tons, 38,000; designed horsepower, 68,000; contract speed (one round trip per year), 24.5 knots.

It is thus seen that the vessel exceeds the *Lusitania* in depth by $1\frac{1}{2}$ inches, and in gross tonnage by 700. Provision is made for 2,165 passengers and a crew of 938, making a total of 3,103. Of the passengers, 563 first-class are carried in 253 staterooms, 35 of which are each for one passenger only; 464 second-class passengers are carried in 133 staterooms; while the third-class, 1,138 in number, are carried in 278 rooms with from two to eight berths each. The seating accommodation of the various dining saloons are 470 in the first-class, 251 in the second-class and 520 in the third-class.

While externally and internally the *Lusitania* and the *Mauretania* are similar in the main features of their design and ar-

rangement, there are differences in detail that are readily apparent. What most strikes one on approaching the *Mauretania* is the difference in the overhead deck erections. Where the *Lusitania* has square trunks with hinged covers for the ventilation of the stokeholds, the newer ship has wide-mouthed ordinary cowls, and, as they are a good deal higher, they somewhat enhance the appearance of the vessel. Then, again, the promenade deck and also the boat deck above project over the shelter deck by about two feet for nearly three-fourths of the length of the vessel. This, on the two decks on which this arrangement has been carried out, makes a very appreciable addition to the free space for promenading on both sides of the ship.

Internally, while the arrangement of the various apartments is almost identical in the two vessels, there is an entire contrast in the architectural treatment and decoration. Speaking broadly, the prevailing aspect of the public rooms in the *Lusitania* is one of lightness and brightness, the outcome of a liberal use of light-colored enamels and gilt. In the *Mauretania*, on the other hand, costly woods in their natural colors are relied upon for decorative effect, producing what might be described as an impression of handsomeness and substantiality. Both schemes of decoration are successful in their own way, and preference for the one or the other will differ according to the taste or temperament of the individual. The dining saloon and upper saloon in the *Mauretania* are in oak in the Francis I style, beautifully carved. In the main entrance hall and staircase the design is Italian renaissance, carried out in French walnut, and the same style in the same wood, with the addition of satinwood inlay, is used with fine effect in the smoking room. The library is done in sycamore of a beautiful grey shade, and is furnished in Louis XVI style, and the same style is carried out in the lounge and music room in mahogany, with large tapestry panels flanked by duplicate pillars of grained marble. The staterooms and regal suites of rooms are variously treated in Adams, Georgian and Sheraton styles.

Equal taste, and not much less expenditure, have been be-

stowed on the second-class accommodation, in which the dining saloon is in oak after the Georgian period, the drawing room in maple, in a modified Louis XVI style, the smoking room in mahogany, and the lounge and entrance hall in polished teak. A new feature in the second-class accommodation is a large deck shelter, which must add greatly to the comfort of the passengers in cold or stormy weather. In their degree, the third-class passengers have also been liberally dealt with, both in their dining saloon and sleeping quarters, the latter being exceptionally large and airy, while the former is nicely finished in polished ash.

The ship is propelled by steam turbines of Parsons type. The total heating surface of the twenty-five boilers (twenty-three double-ended and two single-ended cylindrical) is 159,000 square feet (3.65 acres); the grate surface is 4,060 square feet, and the boilers are fitted for Howden's forced draft. The boilers have shells of high-tensile steel, and discharge the products of combustion into four elliptical funnels with outer casings measuring 26 feet fore-and-aft and 19 feet athwartships. The 192 furnaces are of the Morison suspension type, built by the Leeds Forge Company. Each furnace has a separate combustion chamber.

The turbine rotor wheels, which are usually two in number, one at each end of the drum, are supplemented in this case by two inner wheels to stiffen the drum in its great length. The line shafting has a diameter of 22 inches, but in the bearings it is increased to 36 and 52 inches, a conical section being interposed. The bearings are about 5 feet in length. The propellers have a pitch of about 16 feet, and operate at a slip of about 15 per cent.

The disks and gudgeons, as well as the shafts and drums of the turbines, were made of Whitworth fluid-pressed steel, all stiffeners being solid and integral with the drums, with the idea of getting maximum strength and rigidity with minimum weight, and also to avoid distortion or straining in heating up or cooling down. The high-pressure drums are 96 inches in diameter, and the rotors, including bearings, are

45 feet 8 inches long. The blades, in eight stages, vary from $2\frac{1}{2}$ to 12 inches in length. The low-pressure drums are 140 inches in diameter and 48 feet 2 inches long, with eight stages of blades, varying from 8 to 22 inches in length. The astern turbine drums are 104 inches in diameter and 30 feet 1 inch long, with blades from 2 to 8 inches, in eight stages.

In the rotors and lower half casings the usual method of fitting blades has been followed. This consists in first fitting a fixed stop piece, which sets the correct blade angle. This is held in position in the rotor groove by means of a steel wedge. The first blade and packing piece are then inserted, and, after a number are in position, the set is tapped up with a hammer and tool and afterwards calked. The blades are held together and stiffened by wire binding, the brass wire being fitted into a small saw-cut near the upper end of each blade, and passing on to the successive blades in turn. This forms a brass ring extending around the circle of blades near their upper end. In longer blades two such rings are employed, and in the 22-inch blades of the low-pressure turbines are three sets of wires. A fine copper wire is lashed around each blade and its brass binding wire, to hold everything solidly in place, and the entire connection brazed over by means of silver solder.

The turbine blading in the upper half of the casings is on the Willans & Robinson system. "The blade roots are fitted into two solid half rings, which are accurately divided off by machine cuts, and thus give uniform adjustment to the blade pitches and angles throughout. At the outer ends or tips the blades fit, by means of a tang, into a channel-shaped brass ring or shroud. The blading is completed independently in two or more sections before being fitted into the casing. The channel-shaped shroud can be adjusted to reduce the tip clearance, and, should fouling occur, the channel ring would wear away and give its own clearance, or would, perhaps, bend over, thus protecting the blades and eliminating the danger of blade stripping. It will be noted that in this system no separate packing pieces are required, and that the brass-wire

binding and upper wire lacing are required only in the case of the very long blades near the low-pressure end of the low-pressure turbines."*

The numerous pumps and other steam auxiliaries include a large number by G. & J. Weir, Limited, Cathgart, Glasgow. Others are by W. H. Allen, Son & Company, Limited, Bedford; J. H. Carruthers & Company, Limited, Glasgow; Clarke, Chapman & Company, Limited, Gateshead-on-Tyne, and Brown Brothers, Newcastle. In addition, there are pumps by the Liverpool Engineering Company in connection with the refrigerating plant, and pumps by J. Stone & Company, Deptford, London, for the Stone-Lloyd system of watertight bulkhead doors. Heating and ventilating is on the thermo-tank system, by the Thermo Tank Ventilating Company, of Glasgow. Electric lighting is provided by four turbo-generators, each of 375 kilowatts, supplied by C. A. Parsons & Company, Limited, Heaton-on-Tyne.

The stern frame and bracket casting for the two inner propellers is a mammoth piece of work by the Darlington Forge Company, Limited, the weight being 104 tons. The strut frames for the outer propellers weigh together 48 tons, while the rudder, with an area of 420 square feet, weighs 63½ tons. The stem bar and stem foot piece are respectively an ingot-steel forging weighing 8½ tons, and a cast-steel member of 1½ tons.

There are twelve transverse bulkheads, and intermediate wing bulkheads are fitted in the side bunkers, dividing them into spaces about 40 feet long. Including the double bottom there are altogether 175 watertight compartments. For a distance of nearly 350 feet alongside the boilers the ship has a complete inner and outer skin, not only on the bottom, but also on the sides, being in this respect similar to warship construction.

The maiden trip (Nov. 16 to 22) of this ship was unfortunate by reason of tremendous seas due to a heavy gale. A spare anchor was torn loose, and it is estimated that the total

* J. W. Sothern "The Marine Steam Turbine."

loss in time occasioned by this and the storm aggregated seventeen hours. As it was, however, the distance of 2,780 nautical miles between Daunt's Rock and Sandy Hook lightship was covered in 5 days 5 hours and 10 minutes, at an average of 22.21 knots. On one single day, however, the ship covered 624 nautical miles, which makes the day's run at the rate of 24.99 knots. This is six miles more than was covered by the *Lusitania* in her highest day's run, a few weeks previous, and makes a new record. During this run the *Mauretania's* revolutions averaged 172 per minute, and did not exceed 180. On her trial trip, however, the revolutions reached as much as 194 per minute, the average speed for more than 1,200 miles having been a little over 26 knots. During a portion of this time the speed was 26.75 knots, and one run of 300 miles is stated to have shown no less than 27.36 knots, by far the highest speed ever shown by any vessel over 300 feet in length.—"International Marine Engineering."

A Large French Steamer.—The steamship *Malte*, built to the order of La Compagnie des Chargeurs Réunis, of Paris and Havre, by Swan, Hunter & Wigham Richardson, Wallsend-on-Tyne, is the first merchantman of the French fleet built especially for an all-around-the-world service.

This steamer has the following particulars: Length between perpendiculars, (147.21 meters) 483 feet; breadth, (16.95 meters) 55 feet 8 inches; depth, (10.36 meters) 34 feet; draught, full loaded, (7.32 meters) 24 feet; gross tonnage, 8,321 tons; net tonnage, 5,606 tons; deadweight capacity, 9,500 tons; indicated horsepower, 5,800; mean full speed on trials, 14.5 knots.

This steamer is given the highest class in the French Veritas. She has been built on the deep frame and girder system, and is rigged as a two-masted schooner. There are three decks worked from stem to stern; above the main deck there is a top-gallant forecastle, 55 feet in length, in which the crew, the petty officers and stewards are berthed.

Amidships there is a long bridge house, 182 feet in length,

in which accommodations are provided for fifty-seven first-class passengers in very roomy cabins; the staterooms being situated in the bridge, on the bridge in deck houses, and also in deck houses above that again. The dining saloon is at the front end of the bridge, and a drawing room and a smoking room are also provided, with several "en suite" rooms. The furnishing and outfit are severely plain, but they are especially suited for hot climates. Accommodations are also provided for steerage passengers, who will be located in the first 'tween deck. Aft there is a full poop, with accommodations for officers and a few passengers; the poop has a total length of 33 feet 6 inches.

The ship is divided into eleven watertight compartments, and a complete cellular double bottom extends from end to end. The total capacity of water in this double bottom is 1,322 tons; fore and aft in peaks 210 tons, and in special holds amidships 1,982 tons of water might be shipped; the total water carried on ballast trim therefore is 3,514 tons, which allows good seaworthiness to the ship for running long distances on ballast.

The main 'tween decks are very high, which allows the carrying of horses or cattle. The handling of the cargo has been specially well studied. There are not less than fourteen powerful winches, with latest type of derrick accommodations; the most powerful winch can lift 40 tons, and the smallest 5 tons. Everything has been designed for a quick discharging or loading of the cargo.

The ship is fully equipped with the most modern conveniences, including electric light and a complete refrigerating plant on Hall's CO_2 system, which allows the ship to carry perishable cargo.

The vessel is propelled by twin screws, driven by two engines of the triple-expansion, three-cylinder type, which, at ninety revolutions per minute, have developed an average of 5,800 indicated horsepower. The contract conditions as regards speed were somewhat severe, the vessel having to run for a 4-hour full-power trial, and subsequently a 24-hour con-

sumption trial. On September 2 last, during the former, the mean indicated horsepower developed considerably exceeded the guaranteed power; the 24-hour trial was equally successful, the vessel attaining a mean speed of over 14½ knots, the guaranteed speed being only 13½ knots.

The main engines have cylinder diameters of 25½, 43 and 70 inches, and the stroke is 48 inches. The main and auxiliary engines receive steam from six cylindrical boilers of the usual type, being 11 feet 9 inches in length and 15 feet 3 inches in diameter; there are 18 furnaces. The total surface of grate is 366 square feet, and the heating surface 15,660 square feet, giving a ratio of 42.8 to 1. The boilers are fitted with Howden's forced-draft system. The normal pressure in the boilers is 200 pounds per square inch.

The steamer came to St. Nazaire with 9,000 tons of coal and was measured by customs officials; afterwards she made her official trials for the "subsidy," and then took 5,000 tons of patent fuel for the Saigon dockyard. On leaving St. Nazarre she went to Antwerp, then to Dunkirk, and has left for her maiden trip *via* Suez Canal, Singapore, Hong Kong, Shanghai and other Eastern ports; thence *via* the Pacific to various ports on the west and east coast of South America, and subsequently to the United Kingdom, France and Antwerp. Such a trip is expected to last 240 days.—"International Marine Engineering."

Japan's First Turbine Steamer.—The first turbine steamer for the mercantile marine of Japan has been built by William Denny & Brothers, Dumbarton. The steel turbine steamer *Hirafu Maru* was the first of two vessels ordered by the Japanese States Railway for special service in the Tsugaru Straits. The launch was noteworthy as marking the introduction of the turbine to Japan and also because the ceremony was purely Japanese.

The ship has a length of 280 feet; breadth, 35 feet, and depth, 21 feet 6 inches. She has been built under special survey of Lloyd's register, and in accordance with the requirements of the British Board of Trade and of the Teishinsho rules. The

turbine machinery, which is supplied by Denny & Brothers, was designed to maintain a mean speed of 18 knots. On trial in the Firth of Clyde the speed obtained was 19.08 knots.

There is accommodation for first, second and third-class passengers. The first-class passengers are located in a deck house on the awning deck. Large cabins, having Pullman berths, are provided for ladies and gentlemen, in addition to the ordinary staterooms, and a special stateroom on the boat deck. The first-class dining saloon is designed in the Louis XVI style, and has a very high roof, the upper paneling of which is divided in leaded glass panels representing ancient shipping and other marine subjects. The ceiling, which is tastefully paneled like the rest of the apartment, is finished in white and gold. The sideboards and doors are of same design, the latter having the company's crest worked in leaded glass. The main vestibule is framed in light oak, dull polished. The second-class passengers are located in a deck house abaft the boiler, both classes having sheltered promenades underneath the boat deck, in addition to which the first-class passengers have a promenade on the boat deck itself. The third-class passengers are accommodated in Japanese style at the after end of the main deck. Forward of this is accommodation for officers and engineers and the crew.

A large room is provided for mails, with suitable accommodation for the mail officers. Ample bathing accommodation is provided for all classes, as customary in Japanese vessels. The firemen and cooks, etc., are accommodated on the lower deck, which is fitted in the forward hold. Provision is made for a limited amount of cargo in the main and after holds.

The vessel is fitted with a balanced rudder of the builders' special type, actuated by a steam and hand-steering gear controled from the flying bridge. The anchors, which are of the stockless pattern, are worked by powerful steam windlass, while a warping winch aft enables the vessel to be easily handled in harbor.—"International Marine Engineering."

Berechnung und Konstruktion der Schiffsmaschinen und Kessel. By Dr. G. Bauer, Engineer-in-Chief of the Vulcan Works, Stettin. 3d edition. Munich and Berlin: R. Oldenbourg, 1908.

This, the third German edition of Dr. Bauer's well known work on reciprocating marine engines and boilers, is of the same high character as the preceding editions. It has been enlarged by the addition of valuable information both in the text and in illustrations, and is, in all respects, an excellent work.

OBITUARY.

JACKSON McELMELL, CHIEF ENGINEER (REAR ADMIRAL) U. S. N., RETIRED.

By W. M. McFarland, Member.

On May 31, 1908, there passed away one of the most beloved officers of the Navy and one whose influence on the younger officers of the Engineer Corps was all for good and far reaching in its effects. It is probable that Admiral McElmell was almost the only officer in the Service who knew personally every officer in the Engineer Corps, as all of them had been before him at least once and most of them twice to be examined for promotion.

Admiral McElmell was born in Philadelphia June 4, 1834, the oldest son of James and Katherine McElmell. After a preliminary education in the public and private schools of Philadelphia he attended Holy Cross College at Worcester, Mass., from which he received the degree of Master of Arts. With a natural aptitude for mechanics and a fondness for the sea, he decided to become a naval engineer. As the technical schools are all of more recent date than this period in his life, he secured the technical experience needed by spending two years with the well known ship and engine building establishment of Neafie & Levy, of Philadelphia. As a further training, he served for a short time on a merchant steamer, and then, in August, 1855, entered the Navy as Third Assistant Engineer, his first duty being on the Coast Survey Steamer *Hetzel*, where he assisted in the survey of the sounds of North Carolina.

In 1857 he was fortunate enough to be ordered to the Steamer *Niagara*, which, as is well known, laid the first At-

lantic cable. In this work Admiral McElmell had quite an important part, as he was specially detailed to look after the machinery for the laying of the cable. For his share in the work he later received a gold medal from the New York Chamber of Commerce. In 1858 he was attached to the *Memphis*, one of the "mosquito fleet," which was sent to demand reparation from Paraguay for firing on an American vessel.

After further routine sea duty we find him as First Assistant Engineer on the *Powhatan* at the beginning of the Civil War. He was engaged in active sea duty from the beginning to the end of the great conflict and took part in a number of important engagements; among these were the attack on Forts Jackson and St. Philip, guarding the approaches to New Orleans, and the bombardment of the batteries at Vicksburg in June, 1862. From 1863 to 1865 he was Chief Engineer of the *Richmond*, and during that time participated in the memorable battle of Mobile Bay under Admiral Farragut.

His service after the Civil War comprised the usual alternation of sea and shore duty, much of which was necessarily of a routine character, owing to the almost complete stagnation in our naval progress at that time. However, he had an active part in the early work of developing the League Island Navy Yard. His last sea service was as Fleet Engineer of the North Atlantic Station, on the *Tennessee* and on the *Richmond*, ending in December, 1887.

During previous shore duty he had been a member of the Naval Engineers' Examining Board, and on March 6, 1888, he was ordered to duty as President of that Board and continued as such until he was retired in June, 1896. During the war with Spain and for a short time afterwards he was again placed on active duty and detailed to this same duty for about a year, during which time he not only examined the regular engineers who came up for promotion but also the great majority of those who were appointed volunteer engineers for the war.

This work on the Examining Board was undoubtedly the most important part of his naval career. To be an ideal examiner is rather difficult. Duty to the Government requires a rigid test of the candidate's ability, while tender-heartedness might lead to undue leniency. Admiral McElmell was one of the few who were able to maintain the golden mean. Every man who appeared before him knew that he must be thoroughly prepared or he would not be passed, but on the other hand he knew that there would be no attempt to confuse or discourage him, and that the strict examiner was at the same time a sympathetic friend. The result was that every man was stimulated to do his very best, both in preliminary preparation and in his actual work before the Examining Board.

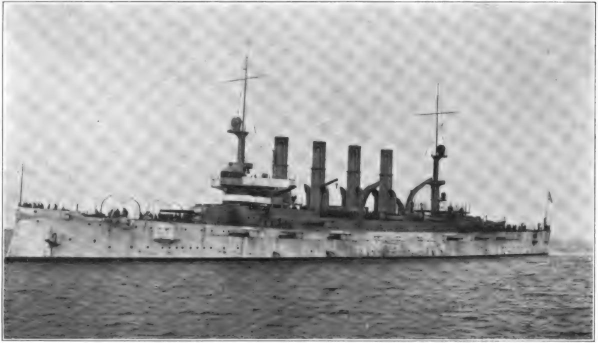
Admiral McElmell had that fine *esprit de corps* (which unfortunately has not been the characteristic of all senior officers in our Service) which made him feel that, although discipline required recognition of difference in rank, junior officers were still brother officers, and when duty had terminated and social relations could be considered he was a charming friend. The writer and the many others who were examined by him will never forget his personal courtesies extended outside of the examining room. Indeed, so great was the affection which they all entertained for him that since his retirement, whenever in Philadelphia, they made it a point to call and spend a social hour with him.

His long detail as President of the Examining Board is a sufficient testimonial of his high professional attainments, but besides being an able engineer, he was a man of broad general culture and literary attainments. As a companion and friend he was altogether delightful, and all who had the privilege of his friendship will for many a day feel a keen regret at the thought that no longer can they enjoy the pleasure of association with him.

In 1869 Admiral McElmell married Miss Mary Thomas and two sons were born to them, but his children died in infancy and his wife soon followed them, so that for a long

time his home had been with a widowed sister and her family and his brother, Mr. Thomas A. McElmell, who was formerly an officer in the Navy. He was a member of the Union League and United Service Club of Philadelphia, the Pennsylvania Historical Society and the Catholic Club of New York. He was for a time Senior Vice-Commander of the Pennsylvania Commandery of the Loyal Legion, of which he was one of the earliest members. When retired he had the rank of Commodore, but by the Act of Congress of June 29, 1906, he was advanced to be a Chief Engineer with the rank of Rear Admiral.

It is not given to every man to make himself famous by some great exploit. While the epochs of history are marked by the men who were heroic, the vast bulk of the world's work is done by those who are faithful in the performance of the duty, however modest, which lies right at hand. And in this work is he not great who does all he can to make those around him happy and always lends a helping hand? Such a man, clean, upright and noble, was Jackson McElmell.



U. S. ARMORED CRUISER "NORTH CAROLINA."

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U. S. ARMORED CRUISER *NORTH CAROLINA*.

DESCRIPTION OF MACHINERY AND OFFICIAL TRIALS.

BY COMMANDER THEO. C. FENTON, U. S. N., RETIRED.

The armored cruiser *North Carolina* is one of two sister ships (the other being the *Montana*) built by the Newport News Shipbuilding and Drydock Company, of Newport News, Va. The contract for this vessel was signed January 3, 1905, the price being $3,575,000. This price does not include the armor and armor bolts (exclusive of protective deck), ordnance and ordnance outfit and certain articles supplied by the Government. The contract time for completion was thirty-six months. Owing to various delays for which the contractor was not responsible, this time was extended to April 27, 1908.

The main engines were required to develop twenty-three thousand indicated horsepower when making one hundred and twenty revolutions per minute, with a steam pressure of two hundred and fifty pounds at the high-pressure cylinder.

The guaranteed speed of the ship was twenty-two knots per hour for four hours.

PRINCIPAL DIMENSIONS OF HULL.

Length on load water line, feet	502
between perpendiculars, feet	502
over all, feet and inches	504–6
Breadth, molded, feet and inches	72–6
extreme to outside of plating, feet and inches	72–10½
Trial displacement, tons, about	14,500
draught to bottom of keel, feet	25
Tons displacement per inch immersion at normal draught	59.70
Bunker capacity to six inches below beams (43.5 cubic feet to the ton), tons	1,954
Capacity of engine-room feed tanks, tons	51
reserve feed-water compartments, tons	192

ELECTRIC PLANT.

There is installed and fitted complete an electric generating plant as follows:

Six 100-kilowatt generating sets, all of 125 volts pressure at the terminals. These sets are located in two independent dynamo rooms, known as the starboard dynamo room and the port dynamo room; three sets in each room.

The generating sets and the engines and dynamos conform in all respects to the latest requirements of the specifications for the United States Navy. Each generating set consists of an electric generator directly coupled to a steam engine, and both mounted on a common bedplate. They are required to run continuously for long periods under full load without variation in speed, with either vacuum or atmospheric exhaust, and worked at pressures twenty per cent. above or below the normal pressure of one hundred and fifty pounds, but only ninety per cent. of the full load need be carried while the engine is working twenty per cent. below the normal pressure on atmospheric exhaust.

ANCHOR WINDLASS.

The anchor windlass is of the vertical type and has two vertical shafts driven by worm gearing direct from a worm located on the crank shaft of the engine, without the intervention of counter shafts or beveled gears. Each shaft carries on its upper end, above the main deck, a wildcat or lock-

ing gear complete. The arrangement is such that the wildcats can be operated together or independently of each other. The wildcats revolve in a horizontal plane, taking in each bower chain on the inboard side and the sheet chain on the outboard side of the wildcats. The vertical shafts have couplings, and the lower end is keyed and supported by steady bearings.

The wildcat is cast from the best open-hearth steel to suit the $2\frac{3}{4}$-inch cable, as manufactured by the Government.

Each wildcat is fitted with a positive locking device worked by raised cams on the periphery of the locking rim and slotted keys operated by means of a lever. The entire operation of locking or unlocking the wildcat can be accomplished by one motion of the lever through an angle not exceeding sixty degrees.

A friction-band brake is fitted to each wildcat. The brakes have sufficient surface and ample strength in all parts to "ride by" with the windlass unlocked. Each end of the friction band is provided with a compressor, so that the bower or starboard chain can be checked when running out. The compressor is controlled by a screw hand wheel set close to the wildcat.

The windlass engine is designed for a working steam pressure of one hundred and fifty pounds per square inch, but is able to withstand the full boiler pressure.

The windlass was fully tested on the official trials of the vessel as follows:

The starboard anchor was let go in thirty-three fathoms of water and the chain veered to sixty fathoms; then the port anchor was let go and both chains veered until the starboard ninety-fathom shackle was at the hawse pipe and the port sixty-fathom shackle at the controller. The wildcats were connected, and both chains hove in simultaneously, at a uniform speed, until the port anchor was at the hawse pipe. The rate of heaving in both chains together was six fathoms in 42.6 seconds. The port anchor was at the hawse pipe in 6 minutes 52 seconds. The port wildcat was disconnected

and the starboard anchor was up in 3 minutes 46 seconds. The wildcats took the shackles and swivel without surging. There was no heating of thrust block or worm wheels.

STEERING ENGINE.

The steering gear is located aft in the compartment provided for it, and is of the standard type of the Bureau of Construction and Repair, consisting of a right- and left-hand screw with traversing nuts directly connected, by side rods, to a crosshead on the rudder stock. The crosshead is secured to the rudder stock by keys. The weight of the rudder is transmitted to this crosshead by means of a wrought-steel ring fitted in a rabbet near the head of the rudder stock, between the crosshead and the casting on the stern post. A floating disc of phosphor bronze is fitted and recessed in the stuffing-box casting to hold oil, the weight of the rudder being taken by this floating ring. The casting is bolted to the stern post, taking the weight of the rudder through this floating ring, and is fitted with a stuffing box around the rudder stock capable of adjustment to convenient location in the steering space. A friction band is fitted to the rudder stock to be operated from the engine steering room.

The steering engine is of compact and efficient design, and is capable of putting the rudder hard over in twenty seconds, when the vessel is moving ahead at full speed, at a working steam pressure of one hundred and fifty pounds per square inch. The engine is of sufficient strength to withstand the operation under full boiler pressure.

Provision is made in the steering-engine room for hand steering on a shaft geared to the main screw shaft. A slip joint is provided between the engine and screw shaft to take up the lateral motion.

Direct hand steering is also provided for in an emergency, by suitable arrangement of relieving tackles, directly connected to the crosshead on the rudder stock. The hand-steering wheels are arranged to be thrown out of gear when the engine is at work.

The steering gear was fully tested on the official trials, and found entirely satisfactory.

PROPELLING MACHINERY.

The propelling engines are right and left, and are placed in watertight compartments, separated by a middle-line bulkhead.

The engines are of the vertical, inverted cylinder, direct-acting, triple-expansion type. The order of the cylinders, beginning forward, is forward low pressure, high pressure, intermediate pressure and after low pressure. The forward low-pressure and high-pressure cranks are opposite, also the intermediate and after low-pressure cranks, the second pair being at right angles with the first. The sequence of cranks is, therefore, high pressure, intermediate pressure, forward low pressure and after low pressure.

The main valves are worked by the Stevenson link motion with double-bar links. There is one piston valve for the high-pressure and two each for the intermediate and low-pressure cylinders.

The framing of the engines consists of forged columns trussed by forged-steel stays. The engine bedplates are of cast steel supported on the keelson plates. The crank, line and propeller shafting is hollow. The shafts, piston rods, connecting rods and working parts generally are of forged steel.

REVERSING GEAR.

The reversing gear for each engine consists of a steam cylinder, and an oil-controlling cylinder bolted to the high-pressure cylinder. The common piston rod of the reversing-gear cylinders acts directly on arms keyed to the reversing shaft. The piston rod passes through the controlling cylinder with a uniform diameter.

The valve of the steam cylinder is of the piston pattern, of composition, working in a composition-lined valve chest.

There is a by-pass valve on the oil cylinder, worked by a

continuation of the stem of the steam-piston valve. These valves are worked by a floating lever, the primary motion being derived from the hand lever on the working platform and the second motion from the reversing shaft, all parts being so adjusted that the reversing shaft follows the motion of the hand lever and is firmly held when stopped. There is a stopcock in the by-pass pipe of the oil cylinder, and a pump for reversing by hand is connected to the oil cylinder with its lever convenient to the working platform. The by-pass pipes are connected to the valve box of the hand pump in such a way as to leave the hand arrangements always in gear. The piston of the oil cylinder is packed by two cup leathers.

REVERSING SHAFT.

There is one reversing shaft for each engine, with an axial hole through it. It has arms for the reversing engine and for each link. Each reversing arm for the links is made with a slot fitted with a block, to which the extension links are attached. Each block is adjustable in the slot of its arm by a screw and hand wheel of an approved hand-locking device and is fitted with a suitable index. The slots in these arms are so arranged that the links may be thrown into full backward gear irrespective of the position of the block in the slot; and the length of the slots is such that cutoff may be varied from about $\frac{5}{10}$ to $\frac{75}{100}$ of the stroke.

TURNING ENGINES AND GEAR.

There is installed in each engine room a double engine for turning the main engine with steam of one hundred pounds pressure. This engine drives, by worm gearing, a second worm, which may be made at will to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves, and are made reversible by means of Stevenson links, reversed by hand levers.

Each turning engine shaft is fitted for turning by hand.

PROPELLERS.

There are two 3-blade propellers, both outboard turning, for ahead motion. The blades and hub are of manganese-bronze. The bolt holes in the flanges of the blades are made oval to allow of adjustment of the pitch, and each blade is firmly bolted to the hub and secured from turning by lock plates.

The dimensions of the propellers are as follows:

Diameter, feet	18
Pitch, as set, mean, feet and inches	22–06
adjustable from 21 feet 6 inches to, feet and inches	23–06
Ratio of diameter to pitch	.8
Area, projected, square feet	78
helicoidal, square feet	100
disk, square feet	254.47
Height of lower tip of blade above keel, inches	16.7
Immersion of upper tip of blade at low draught, inches	67.3

After the official trials the pitch was set to 21 feet 9 inches.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	38½
I.P., diameter, inches	63½
F.L.P., diameter, inches	74
A.L.P., diameter, inches	74
Stroke of all pistons, inches	48
Valves, H.P., one for each cylinder, diameter, inches	23
I.P., two for each cylinder, inches	25½
L.P., two for each cylinder, inches	25½
travel of, inches	10½
Piston rods, diameter, inches	8½
axial holes, H.P. and I.P., inches	4½
L.P., inches	5
Connecting rod, length from center to center, inches	96
crosshead end, diameter, inches	8½
crank end, diameter, inches	9½
Crank shaft, number of sections	2
diameter, inches	18½
axial hole, inches	10
length, feet and inches	35–04
Coupling disks, diameter, inches	32
thickness, inches	4½
Crank pin, diameter, inches	20
axial hole, inches	12
length, feet and inches	1–11

Thrust shaft, diameter, inches	$17\frac{3}{4}$
axial hole, inches	$10\frac{1}{2}$
length, feet and inches	$25\text{-}11\frac{3}{4}$
Stern-tube shaft, diameter, inches	$18\frac{1}{4}$
axial hole, inches	$10\frac{1}{2}$
length, feet and inches	$52\text{-}00\frac{1}{2}$
Propeller shaft, diameter, inches	$18\frac{1}{4}$
axial hole, inches	$10\frac{1}{2}$
length, feet and inches	$48\text{-}05\frac{3}{8}$

Thrust shaft and line shaft combined.

CONDENSERS.

Main Condenser.—There is one main condenser in each engine room, oval in form, the inside dimensions being 9 feet 4 inches high, 5 feet 8 inches wide, the top and bottom being struck with a radius of 2 feet 10 inches. The shell is $\frac{5}{16}$-inch thick with two double butt joints, and with circumferential and longitudinal angle and T-bar stiffeners.

The water chests are cast $\frac{5}{8}$-inch thick. The forward chest, being the one for the entrance and exit of circulating water, has a horizontal division plate in the middle fitted with valves which, when open, allow the circulating water to pass overboard direct, the valves being worked by a lever on the outside of the condenser, and it has nozzles for inlet and outlet of circulating water twenty-one inches in diameter.

The condenser-tube sheets are rolled, each in one piece. They are one inch thick, with smoothly finished holes for the tubes, tapped and fitted with screw glands for packing the tubes.

There are 6,292 seamless-drawn tubes in each condenser, $\frac{5}{8}$-inch outside diameter, No. 16 B. W. G. in thickness. The tubes are 14 feet and $\frac{1}{2}$ inch long between tube sheets and are spaced $\frac{15}{16}$-inch between centers. They are supported at two intermediate points by ferrules, $\frac{3}{4}$-inch long, inserted in supporting plates. Baffle plates are fitted to direct the steam over all the tubes.

The cooling surface for each condenser is 14,411 square feet, measured on the outside of the tubes.

The condensers are supported by angle plates riveted between circumferential angle bar stiffeners.

There is riveted to the shell of each condenser a casting with two composition nozzles with faced flanges twenty-seven inches diameter of opening, for attachment of the main exhaust pipes, and a faced flange nine inches in diameter of opening for the auxiliary exhaust pipe.

Cast-steel flanges are riveted to the shell of each condenser and properly faced for an air-pump suction pipe thirteen inches in diameter and for two manholes at the bottom twelve inches in diameter. There is a one-inch connection in the bottom manhole for cleaning the tubes by boiling.

Drain cocks are provided with pipes leading to the bilge.

A copper tank is provided for admitting an alkaline solution into each condenser, the tank having a capacity of five gallons. Zinc protectors and safety valves are fitted.

The material of the condenser is as follows: Shells, steel, class B boiler plate. Baffle plates, steel, class C boiler plates. Tubes, composition: copper 70, tin 1, zinc 29 per cent. Tube sheets and supporting plates are as near as possible the same material as the tubes. Glands are of tubing, and of the same composition as the tubes. Water chests are of composition. All bolts are of bronze.

AUXILIARY AND DYNAMO CONDENSERS.

The material of these condensers is as follows: Shells, steel, class B, boiler plate; tubes, composition, copper 70, tin 1, zinc 29 per cent.; tube sheets, as near as possible of the same material as the tubes; heads, composition.

The cooling surface of the auxiliary condensers is 600 square feet, and of the dynamo condensers 700 square feet, measured on the outside of the tubes.

In each engine room there is an auxiliary condenser connected from the auxiliary exhaust pipe to all the auxiliary machinery. Each condenser has an air and a circulating pump.

In each dynamo room there is an auxiliary condenser for

the exclusive use of the dynamo engines. Each has an air and a circulating pump. The tube sheets are one inch thick. The diameter and the spacing of the tubes and the packing are the same as in the main condensers.

The tubes of the auxiliary and the dynamo condensers are of the same length.

EVAPORATING AND DISTILLING PLANT.

The evaporating and distilling plant is placed on the protective deck. There are four evaporators and four distillers with their accessories.

The evaporators have a combined capacity of 23,000 gallons of water per twenty-four hours.

The distillers have a combined capacity of 23,000 gallons of potable water per twenty-four hours.

The evaporators take steam from the auxiliary steam pipe, and the coil drain pipes lead through a by-pass, automatic traps, to the feed tanks. The evaporator feed- and fresh-water pumps take steam from the evaporator coils, as well as from the auxiliary steam pips.

The shells of the evaporators have connections with valves and pipes for directing the steam into the distillers and into the auxiliary exhaust pipe.

The feed water for the evaporators is taken from the circulating pipe, after it has passed through the distillers, and from the sea.

There are blow pipes of ample size, so arranged that the evaporators may be blown out when working under pressure.

The distiller circulating pumps discharge to the distillers, the water passing overboard or into the sanitary pipe at will. There is also a direct connection from this pump to the sanitary pipe, and the relief valve for the distillers is so placed as to act for both the distillers and the sanitary pipe.

In addition to the pump connection for distiller circulating, provision is made for circulating water through the distillers, from the most conveniently located discharge pipe from the pump to the fire main.

A small reservoir tank, fitted with a removable cover, is placed in the fresh-water pump suction between the pump and the distillers.

A water meter, without lead, is placed in the pipe connecting the reservoir tank with the bottom of the distillers.

Evaporators.—There are four horizontal evaporators, each having 320 square feet of tube-heating surface.

The tubes are two inches outside diameter and are without bends.

The tubes are secured to the tube sheets so that adequate provision is made for expansion, and the tubes are so arranged that their removal will leave the shell accessible in all its parts for scaling.

All tubes are easily removable for cleaning and repairs, and there are no internal detachable joints in the tubes.

Distillers.—There are four distillers, each having 115 square feet of tube-cooling surface, measured on the outside of the tubes.

The tubes are straight, $\frac{5}{8}$-inch outside diameter, tinned on both sides, and well expanded and sweated into the tube sheets.

Provision is made for the expansion of the tubes by the use of a flanged tube sheet working a stuffing box.

FEED-WATER HEATERS.

In each engine room there is a feed-water heater with all necessary fittings complete.

The heating surface of each heater is 1,150 square feet, measured on the outside of the tubes. They are of the direct-flow type, located on the discharge side of the main feed pumps.

The heating agent is the auxiliary exhaust steam.

The tubes are $\frac{5}{8}$-inch outside diameter, No. 16 B. W. G.

PUMPS.

The pumps are in accordance with the following table:

Auxiliary.	Number.	Type, make and location.	Steam cylinders.					Water cylinders.			
			Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.	Constant "K" (mean of both ends).	Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.
Main air pumps.	2	Cameron, twin, vertical bucket, single-acting, one in each engine room.	2	14	2¾	18	.00686	2	35	3½	18
Main circ. pumps.	2	Centrifugal, driven by compound engine, one in each engine room.	2	H.P., 11	2¼	10	.00235	...	...	...	...
				L.P., 22	2¼	10	.00955	...	...	...	...
Main feed pumps.	4	Cameron, vertical piston, double-acting, single, two in each engine room.	1	16	2¾	18	.009	1	[illegible]	3	18
Aux. feed pumps.	4	Cameron, vertical piston, double-acting, single, one in each starboard fireroom.	1	12	2¼	12	.00337	1	8	2¼	12
Reserve feed-water pump.	1	Cameron, vertical piston, double-acting, single, starboard engine room.	1	5	1	6	.00029	1	6	1	6
Fire and bilge pumps.	6	Cameron, vertical piston, double-acting, single, one in each engine room.	1	12	2¼	12	.00337	1	10	2¼	[illegible]
		One in each port fireroom.	1	10	1¾	12	.00234	1	[illegible]	2	12
Auxiliary condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1½	12	.00084	1	10	1½	[illegible]
Dynamo condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1½	12	.00084	1	10	1½	12
Evaporat. and distill. plant.	2	Evaporating feed pump, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	2	Distilling fresh-water pumps, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	1	Distilling circulating pump, Cameron, horizontal piston, double-acting, single, starboard evaporating room.	1	12	2¼	12	.00337	1	14	2¼	[illegible]
Ice machine.	1	Distilling circulating pump, centrifugal, driven by De Laval st. turbine, port evaporating room.	...	...	...	...	...	...	...	...	...
	2	Allen dense-air, H. B. Roelker, berth deck, starboard, forward	1	9½	1½	13	.00242	...	...	...	...

BOILERS.

There are sixteen Babcock & Wilcox boilers of the latest improved type, placed in eight watertight compartments.

The steaming capacity is such that all steam machinery on

board can be run at full power with an average air pressure in the firerooms of not more than two inches of water. The following list gives the particulars of these boilers:

Length, feet and inches	9–01½
Width, external, feet and inches	16–00½
Number of furnaces	2
headers	27
Grate surface, one boiler, square feet	99.37
Heating surface, one boiler, square feet	4,250
Grates, length, feet and inches	7–00
width, feet and inches	6.83
Pressure, design, working pounds	265
test, pounds	400
Ratio, G. S. to H. S	42.76
Number of tubes, one boiler, 2-inch	901
4-inch	30
Length of tubes, as fitted, feet and inches	8–02

REFRIGERATING PLANT.

There are two Allen dense-air ice machines, each capable of producing the cooling effect of two tons of ice per day. The cooling pipes from the machines are led into the ice tank, the scuttlebutts and the cold-storage room.

Valves are provided in accordance with the Bureau of Steam Engineering standard arrangement of valves, in the cold-air pipes of refrigerating plant so that the air may go to the cold-storage room direct, or through the ice-making tank, and thence to the cold-storage room and scuttle butts; and also from the ice-making tank direct to the scuttlebutts.

AIR COMPRESSORS.

There are three Westinghouse air compressors in the after part of the port engine room for use in running pneumatic tools in the Steam Engineering department, for blowing soot off the boiler tubes, and for the gas-ejecting system for the guns.

Each compressor has a capacity of about fifty cubic feet of free air per minute, at one hundred pounds pressure. The compressor is driven by steam.

OFFICIAL TRIALS.

Standardization of Screws.—The vessel was tried by the standardized-screw method, progressive runs being made over the measured mile off Rockland, Maine, on January 6, 1908. From the data obtained on these runs the curves shown on Plate 1 were plotted.

It was determined that 118.64 revolutions per minute would be required to make the true contract speed of 22 knots.

The draught and corresponding displacement at the beginning and the end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	24–07⅝	24–03¾
aft, feet and inches	25–10½	25–07
Displacement, tons	14,669	14,470

OFFICIAL FOUR-HOURS' TRIAL.

On January 7, 1908, the four-hours' official trial, prescribed by the contract, was held, the ship steering S.W. by S. The sea was very moderate. The draught and displacement at the beginning of this trial were as follows:

Forward, feet and inches	24–09¼
Aft, feet and inches	25–06¼
Corresponding displacement, tons	14,613

Draught and displacement at end of trial were as follows:

Forward, feet and inches	24–04⅝
Aft, feet and inches	25–06
Corresponding displacement, tons	14,468

The data obtained on this trial were as follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	271.8	
engines, pounds	257	258
H.P. steam chest, gauge, pounds	244	242
1st receiver (absolute), pounds	106	115
2d receiver (absolute), pounds	37	45
Vacuum in condensers, inches of mercury, mean	25.6	24.7

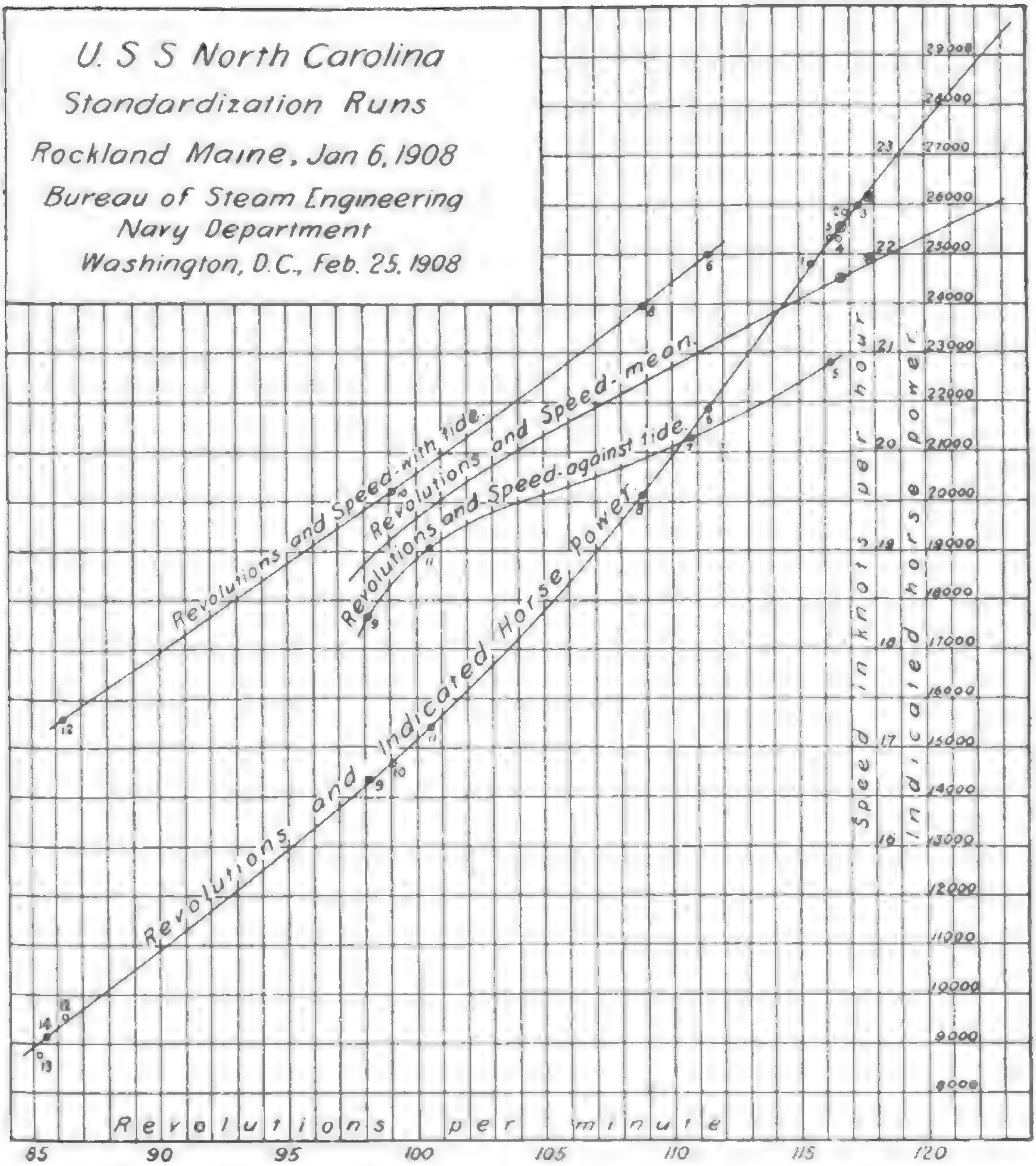

U. S S North Carolina
Standardization Runs
Rockland Maine, Jan 6, 1908
Bureau of Steam Engineering
Navy Department
Washington, D.C., Feb. 25, 1908
Revolutions and Speed-with tide.
Revolutions and Speed-mean.
Revolutions and Speed-against tide.
Revolutions and Indicated Horse power.
Speed in knots per hour
Indicated horse power
Revolutions per minute
85
90
95
100
105
110
115
120
16
17
18
19
20
21
22
23
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000
23000
24000
25000
26000
27000
28000
29000

Plate I.

Temperatures. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Injection, degrees	42	42
Discharge, degrees	107	115
Hotwell, degrees	82	98
Feed water, degrees	173	170
Engine room, working platform, degrees	70	74
Firerooms, working level, degrees	77	
Smoke stacks, average, degrees	605	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Average revolutions, main engines, per minute	118.29	117.62
Pumps, main air	45	45
circulating	210	221
feed, d.s., per minute	31	33
fire and bilge	26	29
auxiliary condenser, air and circulating	48	
Dynamo engines	350	
Blower engines	521.4	
Speed of ship, in knots per hour	21.918	
Slip of propeller, in per cent. of its own speed, based on mean pitch	16.56	16.06
Air pressure in firerooms, in inches of water, mean	2.28	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

	Starboard.	Port.
Main engines, H.P. cylinder	112.8	100.5
I.P. cylinder	50.2	44.8
F.L.P. cylinder	18.6	22.3
A.L.P. cylinder	19.8	23.2
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	52.5	53.9

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P. cylinder	3,675	3,253
I.P. cylinder	4,484	4,373
F.L.P. cylinder	2,287	2,710
A.L.P. cylinder	2,424	2,832
total	12,870	13,168
Collective H.P. of both main engines	26,038	
Air pumps, main	560	
Circulating pumps, main	560	
Feed pumps, main	560	
Hot well	560	
Other auxiliaries	576	
Collective, main and auxiliary engines in operation	27,274	

COAL.

Kind and quality used on trial	New River, hand picked.
Pounds, per hour, main and auxiliary engines, during trial	71,548

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	17.15
Pounds of coal per I.H.P. per hour, main engines	2.748
All machinery in operation	2.623
Square foot of grate surface, per hour	44.96
Cooling surface (main condenser), square feet per I.H.P. main engines	1.0745
Heating surface, square feet per I.H.P. (total)	2.493

The speed of the ship on this trial was 21.914, which was a trifle below the contract requirement. The Department directed that a four-hours' full-power trial be held on February 15, 1908, with the view of obtaining the full contract speed.

This trial was held on the date specified. The weather was generally cloudy, with moderate to fresh breezes from N.W. to W. At the beginning of the trial there was a moderate swell from S.E., increasing to a long, heavy swell at 10.30 P. M., and remaining about the same to the end of the trial. The course was about N.E. magnetic.

The draught and displacement at the beginning of this trial were as follows:

Forward, feet and inches	24-11⅝
Aft, feet and inches	26-00¼
Corresponding displacement, tons	14,847

The draught and displacement at the end of the trial were as follows:

Forward, feet and inches	24-04½
Aft, feet and inches	25-07⅜
Corresponding displacement, tons	14,430

The data obtained on this trial were as follows:

38

	Starboard.	Port.
Average revolutions	123.24	122.12
steam pressure at boilers	291	
H.P. steam chest	253	253
pressure in fireroom, inches water	1.81	
vacuum	25	25
I.H.P., main engines	29,225	
Speed of ship, in knots per hour	22.481	
Slip of propellers, in per cent. of their own speed	17.85	17.09

OFFICIAL TWENTY-FOUR HOURS' ENDURANCE TRIAL.

At 6·00 A. M., January 9, 1908, the twenty-four hours' endurance trial, under all boilers, as prescribed by the contract, was commenced. The weather was partly overcast at the beginning, with light westerly breezes, and a very moderate sea from S.E. During the afternoon and up to 1·00 A. M. the wind increased to a fresh gale, veering and hauling from N.W. to W.S.W. The weather moderated after 1·00 A. M. until clear, with light northerly airs at finish, with a smooth sea.

The data obtained on this trial were as follows:

PERFORMANCE.—TWENTY-FOUR HOURS' OFFICIAL TRIAL.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	243.2	
engines, pounds	232.4	231.6
H.P. steam chest, gauge, pounds	216.8	216.5
1st receiver (absolute), pounds	85.0	96.0
2d receiver (absolute), pounds	27.7	34.0
Vacuum in condensers, inches of mercury, mean	25.7	25.1

Temperatures. (Average of one-half hourly observations.)

Injection, degrees	47	48
Discharge, degrees	113	116
Hotwell, degrees	91	97
Feed water, degrees	183	164
Engine room, working platform, degrees	60	61
Firerooms, working level, degrees	73	73
Smoke stacks, average, degrees	561	

Revolutions, or double strokes, per minute. (Average of one-half hourly observations.)

Average revolutions, main engines, per minute	108.74	107.6
Pumps, main air	30	35
circulating	177	184

	Starboard.	Port.
Pumps, feed, d.s. per minute	19	24
fire and bilge	30	41
auxiliary condenser, air and circulating	53	42
Blower engines	420	
Speed of ship, in knots per hour	20.556	
Slip of propeller, in per cent. of its own speed, based on mean pitch	14.86	13.96
Air pressure in firerooms, in inches of water, mean	1.2	

Mean Effective Pressures in Cylinders, in pounds per square inch. (Averages of cards taken at half-hourly periods.)

Main engines, H.P. cylinder	109.3	108.4
I.P. cylinder	43.2	43.6
F.L.P. cylinder	13.4	14.7
A.L.P. cylinder	15.2	16.1
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	44.7	46.1

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	2,216	3,119
I.P. cylinder	3,486	3,448
F.L.P. cylinder	1,490	1,596
A.L.P. cylinder	1,690	1,757
total	9,882	9,920
Collective H.P. of both main engines	19,802	
Air pumps, main	420	
Circulating pumps, main	420	
Feed pumps, main	420	
Hotwell	420	
Other auxiliaries	443	
Collective, main and auxiliary engines in operation	20,665	

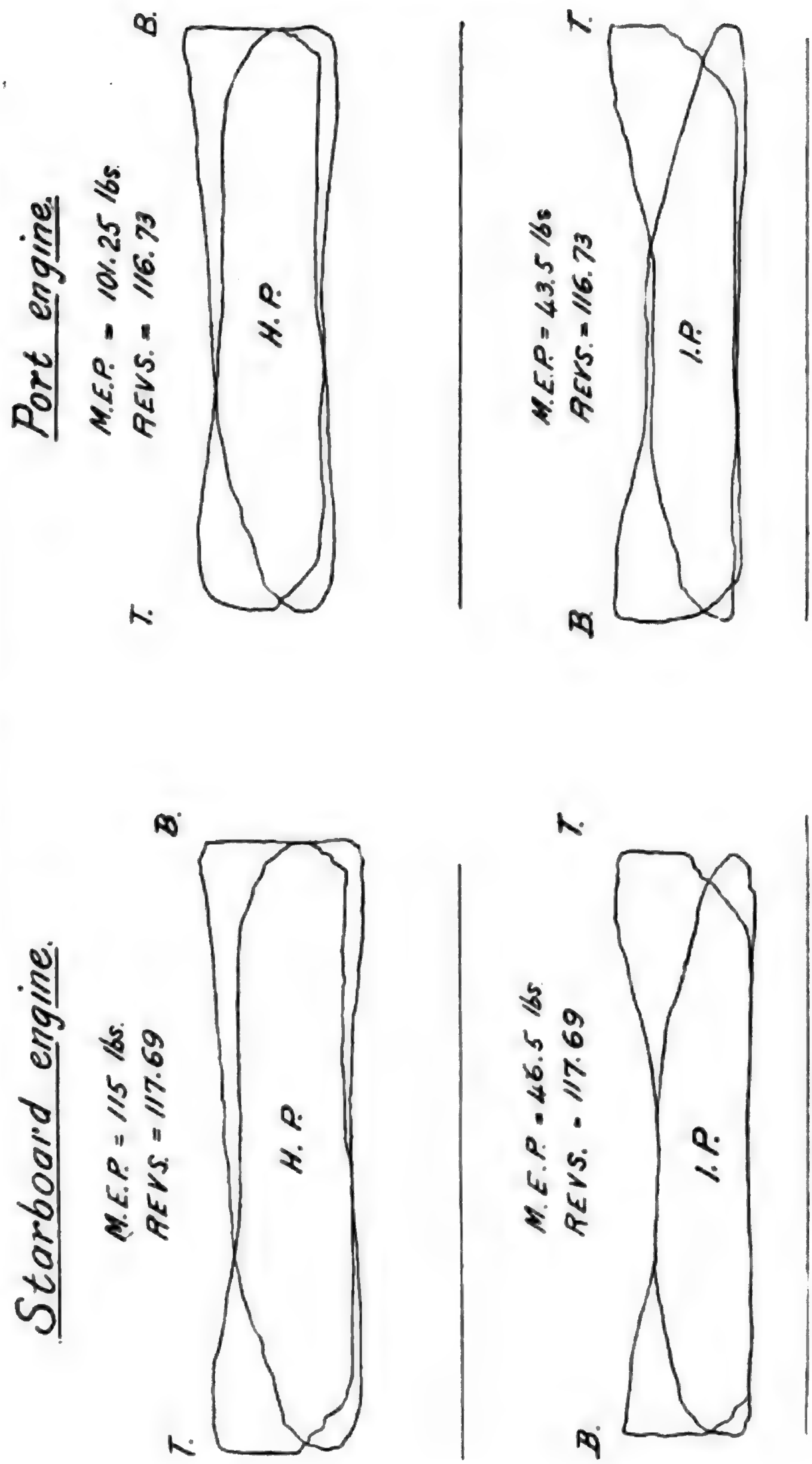
COAL.

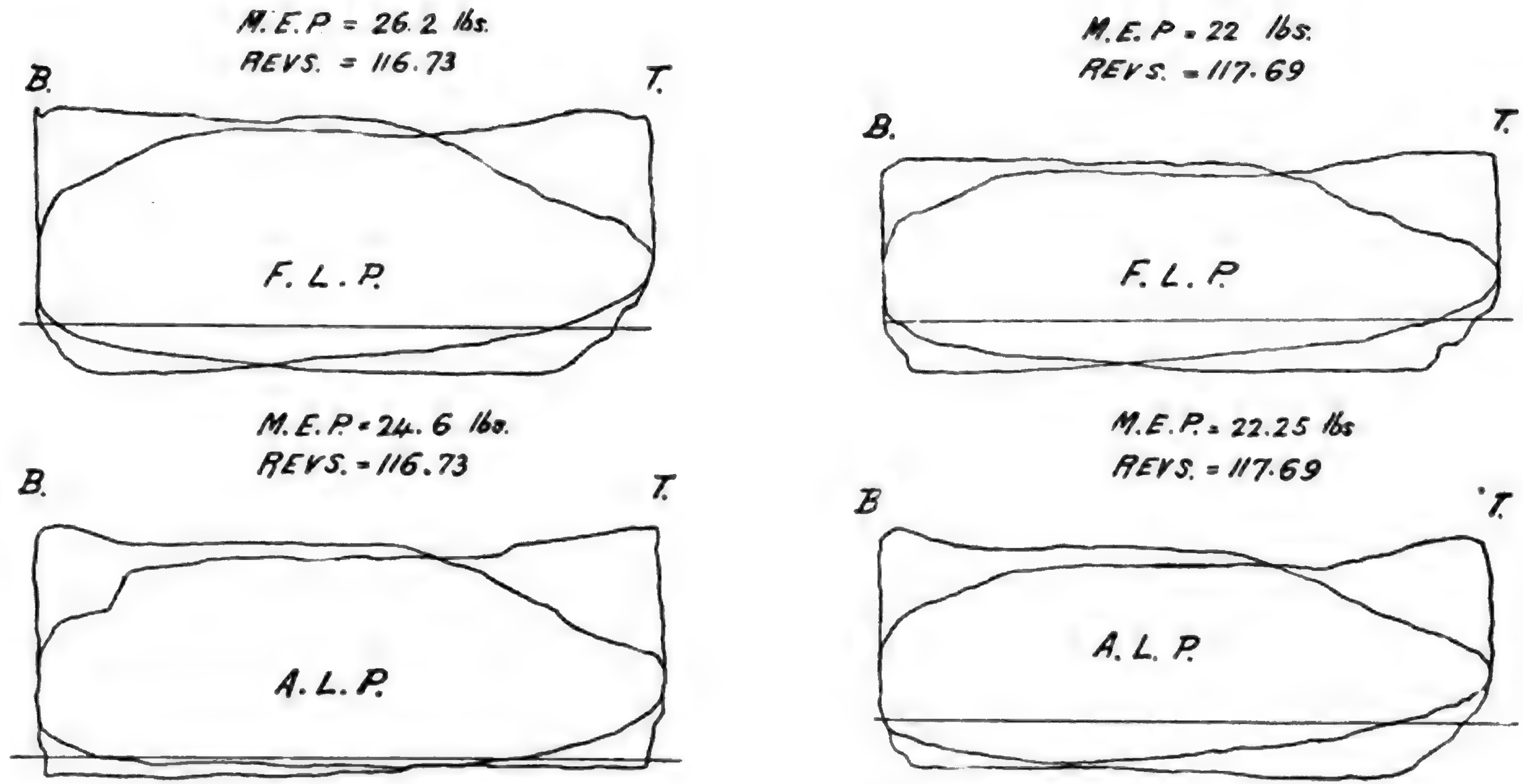
Kind and quality used on trial	New River; poor.
Pounds per hour, main and auxiliary engines, during trial	39,135

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	13.42
Pounds of coal per I.H.P. per hour, main engines	1.98
all machinery in operation	1.87
square foot of grate surface, per hour	24.6
Cooling surface (main condenser), square feet per I.H.P., main engines	1.366
Heating surface, square feet per I.H.P. (total)	3.19

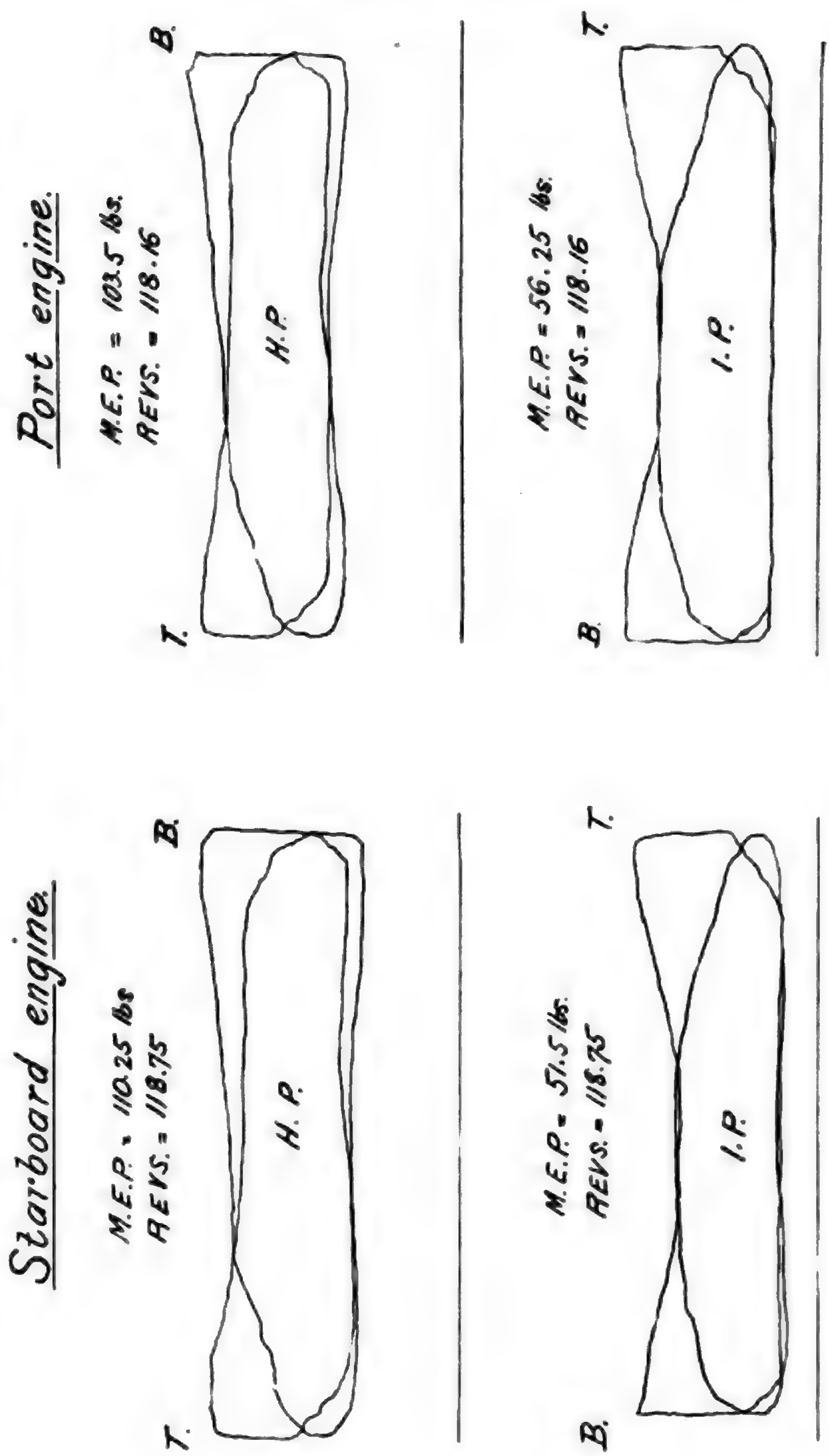
"North Carolina."—Indicator Cards Taken on Four-Hour Trial, January 7, 1908.

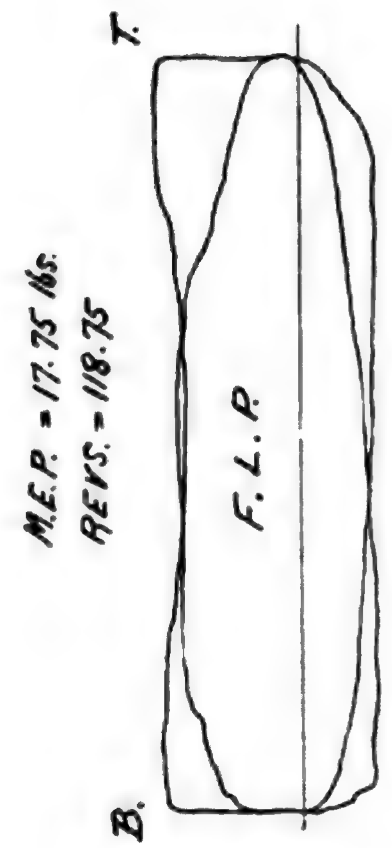


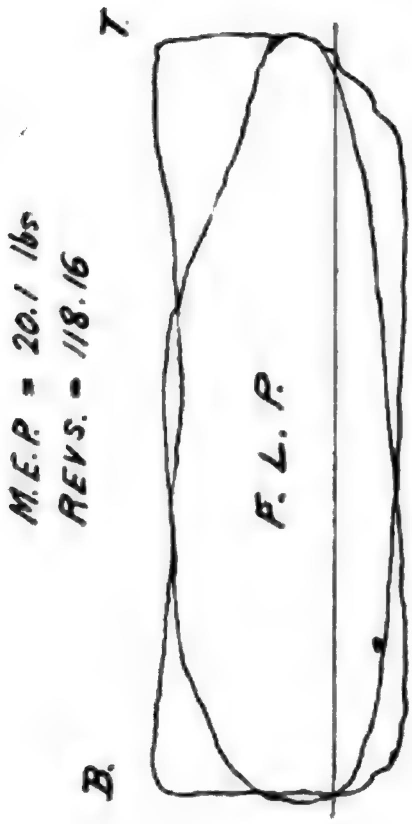


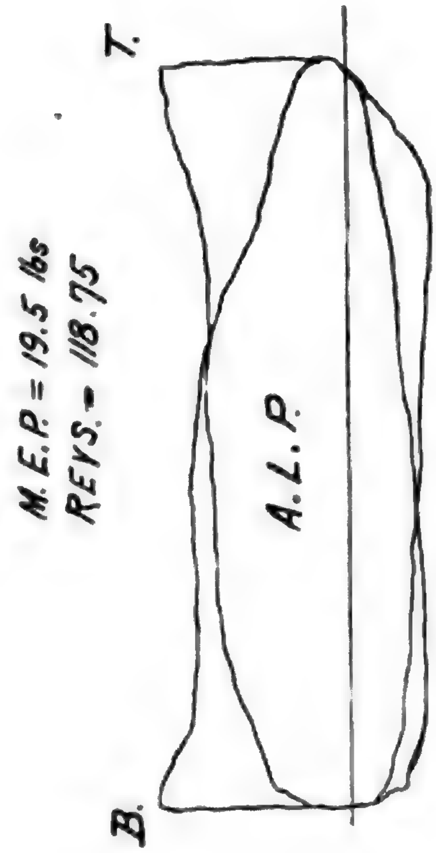
Starboard.		Port.
265	Pressure at engine, gauge	265
250	H.P. chest, gauge	240
107	I.P. receiver, absolute	125.7
42	L.P. receiver, absolute	50.7
25.4	Vacuum, inches	24.3

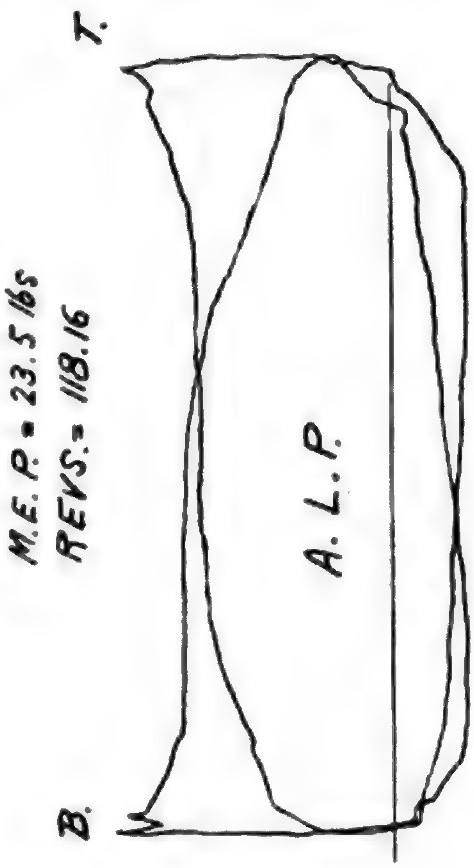
"NORTH CAROLINA."—INDICATOR CARDS TAKEN ON TWENTY-FOUR HOUR TRIAL, JANUARY 9, 1908.



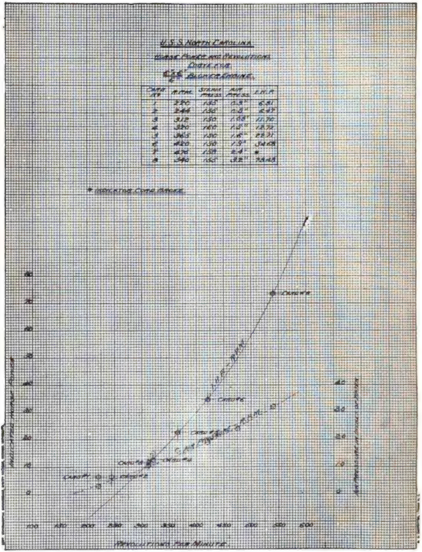








Starboard.		Port.
180	Pressure at engine, gauge	165
175	H.P. chest, gauge	157
77	I.P. receiver, absolute	70
26	L.P. receiver, absolute	23
26.4	Vacuum, inches	25.3



Card No.	R.P.M.	Steam Press.	Air Press.	I.H.P.
1	220	135	0.9"	6.31
2	244	150	1.0"	6.47
3	312	150	1.08"	11.70
4	320	160	1.2"	12.72
5	365	150	1.6"	22.71
6	420	150	1.9"	34.68
7	476	150	2.4"	*
8	540	150	3.2"	73.48

Plate II.—"NORTH CAROLINA." CURVE FOR BLOWER ENGINE.

THEORY OF THE SCREW PROPELLER.

BY VON J. W. HAEUSSLER.

Translated by A. M. P. MASCHMEYER, Associate.

INTRODUCTION.

The adaptation of the steam turbine for marine purposes has given an increasing importance to the design of the propeller, and a need for theoretical formulae for the calculation of the same has been felt. For vessels having reciprocating engines empirical formulae have been deduced for the design of the screw. When the greater number of revolutions of the steam turbine had to be transferred to the propeller these formulae proved useless. For want of knowledge of the theory of fast-turning propellers trials were relied upon; for each new vessel several screws were made, and by trial trips the one giving the highest efficiency was chosen. In the present article the design of the screw will be deduced by mechanics. Efforts in this direction have, to my knowledge, not been published; I have been unable to find anything under kindred subjects that could be compared with my theoretical representations.

The theories of the actions of the screw propellers known up to the present time are deduced from dynamics.

Dynamics and mechanics are correlated conceptions, the former treating of the theory of forces and the latter of the theory of the motions produced by acting forces.

If we consider the action of a propeller as a translation of its torque into a rectilinear work of the vessel, then it is unnecessary to know the magnitude of the hydraulic work;

it will be sufficient if we are able to ascertain in per cent. the loss of work which must be deducted from the work of the screw as loss of the thrust.

The work of the screw is composed as the hydraulic pressure of two components—the axial and tangential components. The former produces the useful work of propelling the vessel, while the latter is the loss in moving the water. The latter again is dependent upon the construction of the screw, as we will see, and can be expressed and subtracted in fractions of the propeller efficiency.

The friction of the screw in the water is also a loss which in a similar manner can be expressed and eliminated by an economical coefficient.

The present article is not intended to prove theoretically the efficiency of any oftentimes unsuitably-designed screw; such generalization would only confuse and make the contents more difficult to understand without serving a useful purpose.

The theory must show the way how to design a screw so as not to conflict with the laws of mechanics, and what dimensions and angles should be adapted for each case.

The mechanical theory of the hydraulic screw as presented by me is closely related to the theory of the aerial screw propeller, and professional circles labor to make it stand for the study of power flight. (*Zeitscher d. V. D. T.*, 1906, No. 43, p. 1766.) To answer both purposes and to be able to use the obtained equations equally well for liquids as for gases has been my object, and therefore the theories have been given in general.

With some modifications the herewith-given theory of the screw propeller can be applied to flying machines, in which two opposed-bladed aerial screw propellers are arranged above each other, and turning in a horizontal plane against each other, so that the slip of the basket or frame which would be caused by the employment of only one screw would be counteracted by the slip of the second screw.

The theory treats first of the reciprocal actions between a

moving fluid and a plane with consideration of the pitch or angle used. After that the obtained equations will be introduced in the mechanic.

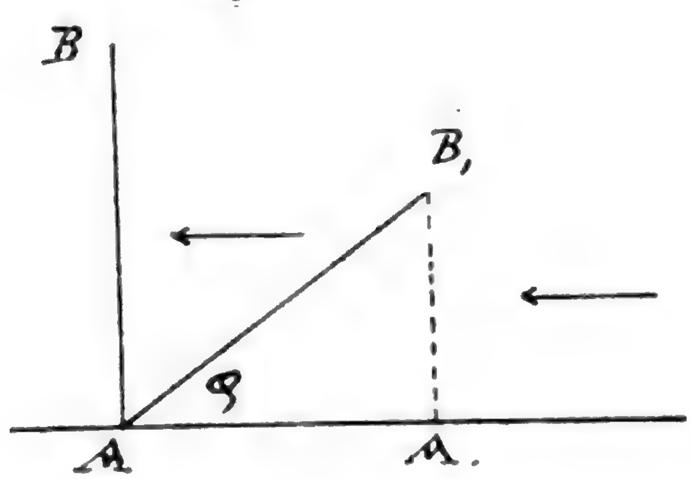
§1.—Pressure of a Moving Fluid Against a Quiescent Plane and of a Moving Plane Against a Quiescent Fluid.

If a fluid (liquid or gas) moves against a plane of length l and breadth b, and p is the normal pressure of the fluid upon the unit surface of the plane, then the total pressure P_1 normal to the plane is

$$P_1 = lbp. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In Fig. 1 line AB represents the breadth b of the supposed plane and the arrows indicate the direction of motion of the

Fig. 1



fluid normal to the plane $(AB)l$. The molecules act against the plane with a pressure equal to the amount expressed by equation (1).

We can also imagine that the plane is oblique to the direction of motion of the fluid, so that its breadth in Fig. 1 can be represented by line AB_1. In this oblique position only as many molecules act against the plane as will pass through the rectangle $(A_1B_1)l$. The total pressure P_2 against the oblique plane is therefore $P_2 = (A_1B_1)lp$.

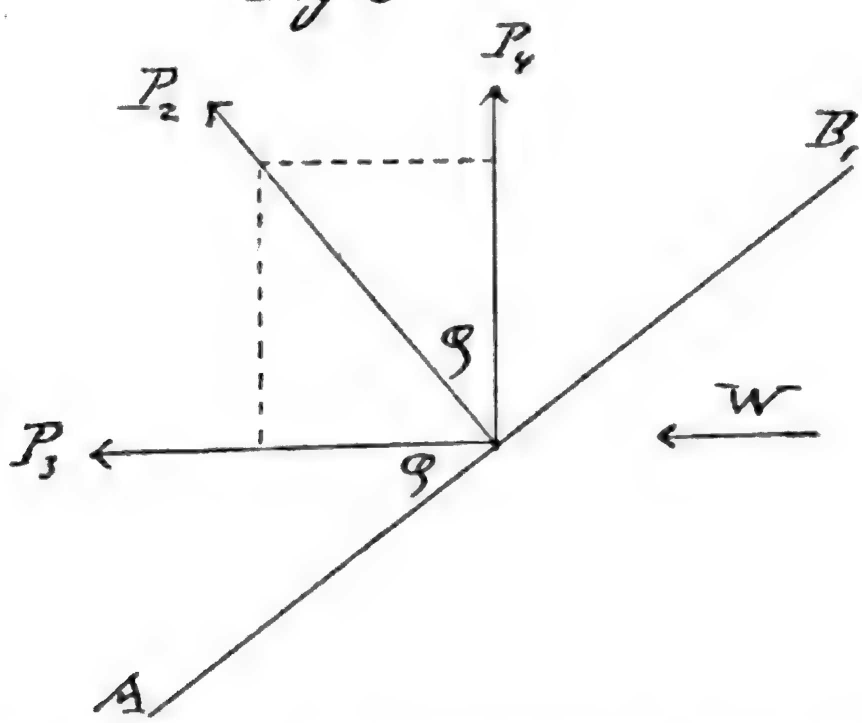
If φ is the angle of the oblique plane with the direction of motion of the fluid, then $A_1B_1 = AB_1 \sin\varphi = b \sin\varphi$.

Substituting this value in the previous equation, the total pressure then becomes

$$P_2 = lbp \sin\varphi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The direction of this pressure is normal to the plane, but the impelling molecules of the fluid continue their motion from the plane through an angle of the same magnitude.

Fig 2



In Fig. 2 the line AB_1 represents again the cross section of the plane, and the arrow W the direction of motion of the fluid; and if plane AB_1 is movable it will be forced in the direction of P_2 which is normal to the plane $(AB_1)l$. The pressure P_2 can be divided into two components normal to each other. The component P_3 in the direction of the moving fluid is

$$P_3 = P_2 \sin\varphi, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

while the component P_4, opposite to the direction of the fluid coming from the plane, is

$$P_4 = P_2 \cos\varphi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This can also be deduced from the parallelogram of forces of which P is the diagonal; for

$$P = \sqrt{P_2^2 \sin^2\varphi + P_2^2 \cos^2\varphi + 2P_2 \sin\varphi\, P_2 \cos\varphi \cos 90^\circ}.$$

But

$$\cos 90^\circ = 0,$$
$$\sin^2\varphi + \cos^2\varphi = 1;$$

therefore

$$P = P_2; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

or substituting for P_2 its value from equation (2)

$$P = lbp \sin\varphi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The component in the direction of motion of the fluid results from the equations (2) and (3)

$$P_3 = lbp \sin^2\varphi, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and the component P_4 normal to the direction of motion of the fluid from equations (2) and (4)

$$P_4 = lbp \sin\varphi \cos\varphi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

In the above considerations it is supposed that the plane is displaced only relatively to its breadth by the direction of motion of the fluid. But a displacement relatively to its length can also be considered. In such case the entering angle φ changes, but a new angle does not enter into the given equations. We can compare the direction of motion of a fluid against a plane with a ray of light that is reflected from the surface of a mirror. As is well known, here only one angle is to be considered, which can be compared with our entering angle φ.

All the given equations are applicable not only to a moving fluid against a quiescent plane, but also vice versa, viz: to a moving plane against a quiescent fluid. The relative change

in position is in both cases the same, as also the resulting pressure. The angle φ is determined by the position of the plane relatively to its direction of motion.

§2. Determination of Pressure p.

The common equation for moving bodies

$$ps=\frac{1}{2}mv^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

which gives the change of kinetic energy into work, cannot be directly employed in the present case for the determination of the specific surface pressure p, but has to be transformed for a constantly recurring work.

Let us consider a fluid of the mass m which constantly moves with a velocity v against a plane.

The molecules repelled by the plane are replaced in the above case constantly by new ones; therefore, if the plane is movable it will be propelled so that the moving molecules exert a constant force upon the plane.

The path s in the above motion equation at the beginning of the work is the product of half the acceleration c by the square of the time t; therefore,

$$s=\frac{c}{2}t^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (10)$$

Substituting this equation in equation (9), this becomes

$$pct^2=mv^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

As soon as the work has a constant value the acceleration c becomes equal to a velocity which increases from the beginning of the work during the time t from value o to value s; therefore,

$$c=\frac{s-o}{t}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (12)$$

Equation (11) becomes through substitution of this value,

$$pst=mv^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (13)$$

Value s in this equation represents, contrary to the same denomination in equation (9), also a distance, but distance of a constant power.

Equation (13) shows the transmutation of kinetic energy into work when a moving liquid with a constant velocity v produces mechanical work.

If the work is given in kg—m—sec, then we can assume in equation (12) for $s=1$ and $t=1$, and transform it to

$$p=mv^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

If the work is given in H.P. then $pst=75N$kg.

The stated assumption represents that the pressure p is opposed to a resistance which in the time $t=1$ is capable of moving it through a distance $s=1$.

Assuming as unit of length the meter and as unit of pressure the kg., then mass m of a weight q of a cubic meter of the respective fluid divided by acceleration or

$$m=\frac{q}{g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Using these equations first for air and assuming the weight of a cubic meter of air at a temperature of 0 degree and 760 mm. barometric pressure of $q=1.29318$ kg., therefore is

$$m=\frac{1.29318}{9.81}=.13182. \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Entering this value into equation (14) we obtain as the theoretical pressure of air acting normal to a surface the relation,

$$p=.13182v^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

This theoretical formula applies only under the supposition that all molecules of air come into contact with the surface. In reality it is impossible to satisfy this assumption, since the molecules returning from the surface will collide with those arriving, and thus prevent the latter from exerting a pressure upon the surface. For this reason the numerical coefficient

in equation (17) results in practice smaller than deduced theoretically. Therefore, the latter equation is corrected by entering a constant C, which represents the value of the economical coefficient, and we have

$$p = .13182 C v^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

The value of C is always smaller than 1, and for air can be readily determined.

The pressure of air flowing perpendicularly against a plane is, as well known, $p = .123 v^2$, and the relation of the two figures gives the value

$$C = \frac{.123}{.13182} = .9331. \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

The diminution of pressure for air amounts to about 6⅔ per cent. for the given reason.

Introducing the constant C in equation (13) and enlarging its meaning and putting it in general,

$$\frac{Co}{st} = C. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

The pressure of a fluid moving normal to a plane with a velocity v is determined from the relation

$$p = m C v^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Let us consider now inversely the case in which a plane moves with a constant volocity v against molecules at rest, so that the latter will be put in motion by the contact. The relative displacement between the molecules and the plane is in both cases alike, and therefore the resulting pressure from the motion must be the same in both cases, even if we add the assumption that the plane is normal to the direction of the motion. Therefore equation (21) can be applied generally in regard to pressure, regardless of the molecular kinetic energy or the work, which may differ in the two cases.

In the case of a moving plane against molecules at rest, v

in equation (21) represents not the velocity of the molecules after impact, but the constant velocity of the plane, or the relative displacement, and m, as before, represents the mass of the molecules, and we can therefore say $m=\frac{q}{g}$.

Applying this equation to the rotating motion of a propeller in water, the weight q of a cubic meter of water must be taken, either for fresh water or sea water, as the case may be. We will use in the equation here the latter, as this principally will have to be considered.

Assuming the mean specific weight of sea water as 1.0274, then the weight of a cubic meter

$$q=1,027.4 \text{ kg.}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

and the relation to the mass

$$m=\frac{1,027.4}{9.81}=104.7. \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

We substitute this value in equation (21), and it becomes then

$$p=104.7Cv^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

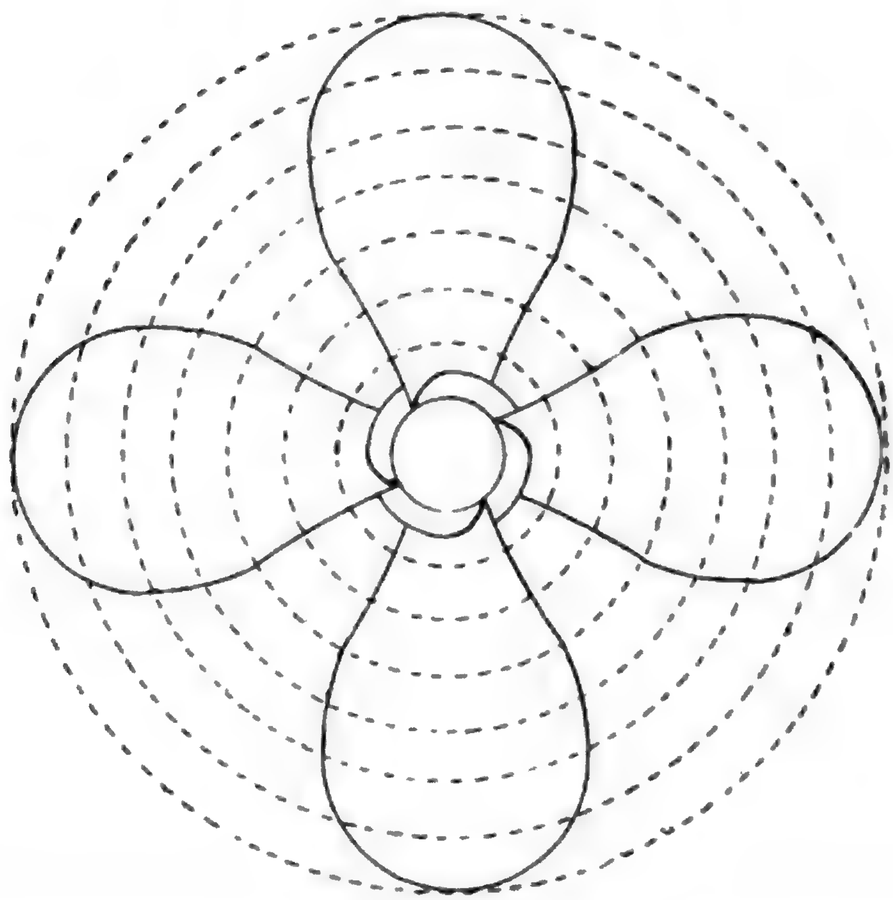
The constant C in this equation for water is yet unknown; but we will learn a method which enables us to ascertain the same experimentally.

In calculating a screw propeller we can assume that the water in which it moves is completely at rest. This condition does not exist in reality, as sea water is always more or less in motion. This motion, however, is relatively small compared with the motion which the water assumes through the rotating motion of the screw, and we shall not commit an error worth mentioning when we assume the water as at rest. The motion of the waves accelerate sometimes the speed of the vessel and sometimes they retard it, and these changeable conditions cannot be considered in the design and calculation of a propeller.

§ 3.—Axial and Tangential Pressure of a Water Wheel with Constant Pitch.

We can imagine every screw as composed of any number of concentric water wheels, with the difference between the outer and inner diameters of each wheel so small that the pitch of the same radially can be assumed as constant in cal-

Fig 3



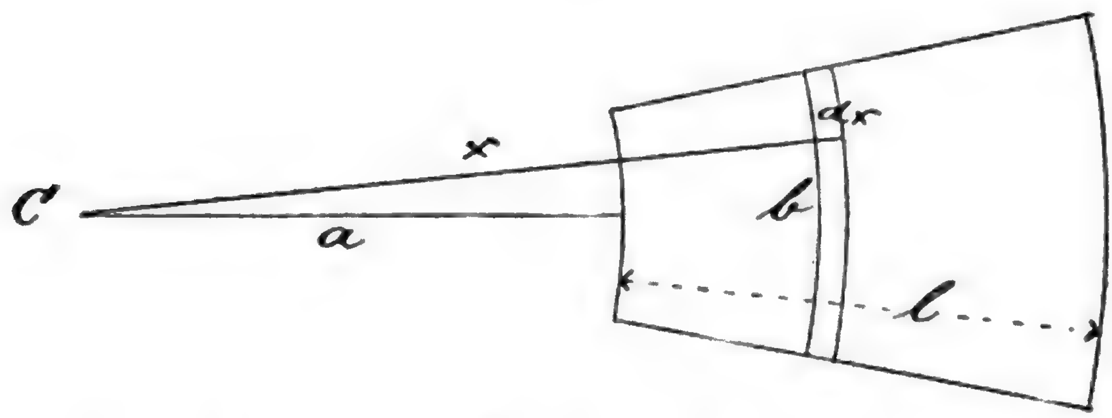
culations for practical purposes. The pitch of these single wheels may be constant or variable in the peripheral direction, but for our calculations we will assume that the pitch is constant also in the line of the periphery.

We will see directly that we can compute the work as well as the surface pressure of each water wheel with a radially-constant pitch. If we add the values found for the separate

wings we will be able to ascertain with sufficient accuracy by this the surface pressure and work of a propeller.

Let us imagine a water wheel constructed similar to the American wind wheels, with flat blades of radial and constant peripheral pitch φ, as shown in Fig. 4, which represents one

Fig 4.



blade of such a wheel. We are able to figure out the surface pressure which the wheel exerts against the water in axial direction during its revolution as follows:

At a distance x from the axis C the breadth of the blade measured on the arc is b, while the radial length is l; and let us assume also that the distance of the blade from the axis is a and that the water wheel has n blades; then the axial pressure of an infinitely small element of the blade of length dx and breadth b for all blades n by equation (8)

$$dP_1 = ndxbp \sin\varphi \cos\varphi. \quad . \quad . \quad . \quad . \quad . \quad (25)$$

For a moving plane in quiescent water we obtained (equation 21) $p = mCv^2$. The former equation by substituting this value becomes

$$dP_1 = mCnv^2dxb \sin\varphi \cos\varphi. \quad . \quad . \quad . \quad . \quad (26)$$

The peripheral velocity v for r revolutions of the water wheel per second, at a distance x from the center, is

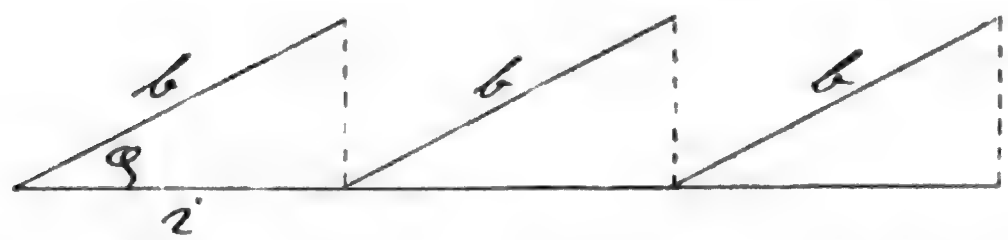
$$v = 2x\pi r, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

and our equation therefore becomes

$$dP_4 = 4mCn\pi^2r^2x^2dxb \sin\varphi \cos\varphi. \quad . \quad . \quad . \quad (28)$$

The breadth b of the blade under consideration has a certain relation to the periphery of the wheel on account of the constant angle φ. Let us picture ourselves a few blades of the water wheel as in Fig. 5, seen from the periphery and

Fig 5



developed in a plane; assume, furthermore, that the wheel is so closely studded with blades that the axial projection i of each blade joins closely that of the adjoining one, then

$$b = \frac{i}{\cos\varphi}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

and as x represents any radial value,

$$i = \frac{2x\pi}{n}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

therefore,

$$b = \frac{2x\pi}{n\cos\varphi}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

Entering this value in equation (28), we obtain

$$dP_4 = 8mC\pi^3r^2x^3dx \sin\varphi. \quad . \quad . \quad . \quad . \quad . \quad (32)$$

Integrating in this equation length x from the initial a to the end value $a+l$ (Fig. 4), we obtain for the total axial pressure of the water wheel the value

$$\int dPax = 8mC\pi^3 r^2 \sin\varphi \int^{a+l} x^3 dx$$

$$Pax = 8mC\pi^3 r^2 \sin\varphi \tfrac{1}{4}[(a+l)^4 - a^4];$$

or entering π numerically,

$$Pax = 62.01 mCr^2 \sin\varphi[(a+l)^4 - a^4]. \quad . \quad . \quad (33)$$

If in Fig. 4 we call the exterior diameter of the water wheel D_a and the interior diameter D_i, then

$$D_a = 2\,(a+l), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

and

$$D_i = 2a. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

Introducing the number of revolutions per minute in this equation, we have to put

$$r = \frac{T}{60}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

These values entered into equation (33) gives the total pressure in the direction of the axis of the rotating wheel of a value

$$P_{ax} = .0010766 mCT^2 \sin\varphi\,(D_a^4 - D_i^4). \quad . \quad . \quad (37)$$

We can deduce similarly the tangential pressure by means of equation (7).

We first obtain for the pressure the value analogous to equation (32),

$$dP_3 = 8mC\pi^3 r^2 x^3 dx\,\frac{\sin^2\varphi}{\cos\varphi}, \quad . \quad . \quad . \quad . \quad (38)$$

and by integration between the same limits, as before,

$$P_{tg} = 62.01 mCr^2 \frac{\sin^2\varphi}{\cos\varphi}\Big[(a+l)^4 - a^4\Big]. \quad . \quad . \quad . \quad (39)$$

Introducing the values of equations (34) to (36) we obtain for the total pressure of the rotating wheel in a tangential direction the equation

$$P_{tg} = 0.0010766 mCT^2 \frac{\sin^2\varphi}{\cos\varphi}\Big[D_a^4 - D_i^4\Big]. \quad . \quad . \quad (40)$$

Equation (37) indicates by what means we can ascertain experimentally the economical coefficient C.

A water wheel as described is made to rotate vertically in ball bearings, and movable in the same direction. Fastened to the lower end of the shaft is the water wheel, and a thread is cut on the upper end of the shaft which serves to receive weights in the shape of threaded disks. If a certain weight is lifted at the number revolutions T, then the vertical pressure P_{ax} equals the total weight G of the water wheel, inclusive of shaft and its load of disks. All values in equation (37) are therefore known excepting the coefficient C, which can be found by transposing the members

$$C=\frac{928.8G}{mT^2\sin\varphi(D_a^4-D_i^4)}. \quad . \quad . \quad . \quad . \quad (41)$$

The mass m will have the value $\frac{1000}{g}$ for sweet water; but for salt water the value given in equation (23) must be used.

Referring back to equation (20), $\frac{Co}{st}=C$, we see that it is immaterial in what path (s) the water is forced back by pressure p. If in reality $st \gtrless 1$, then equation (41) represents always the experimentally-obtained value of C.

§ 4.—Work of the Axial and Tangential Pressure with a Constant Pitch.

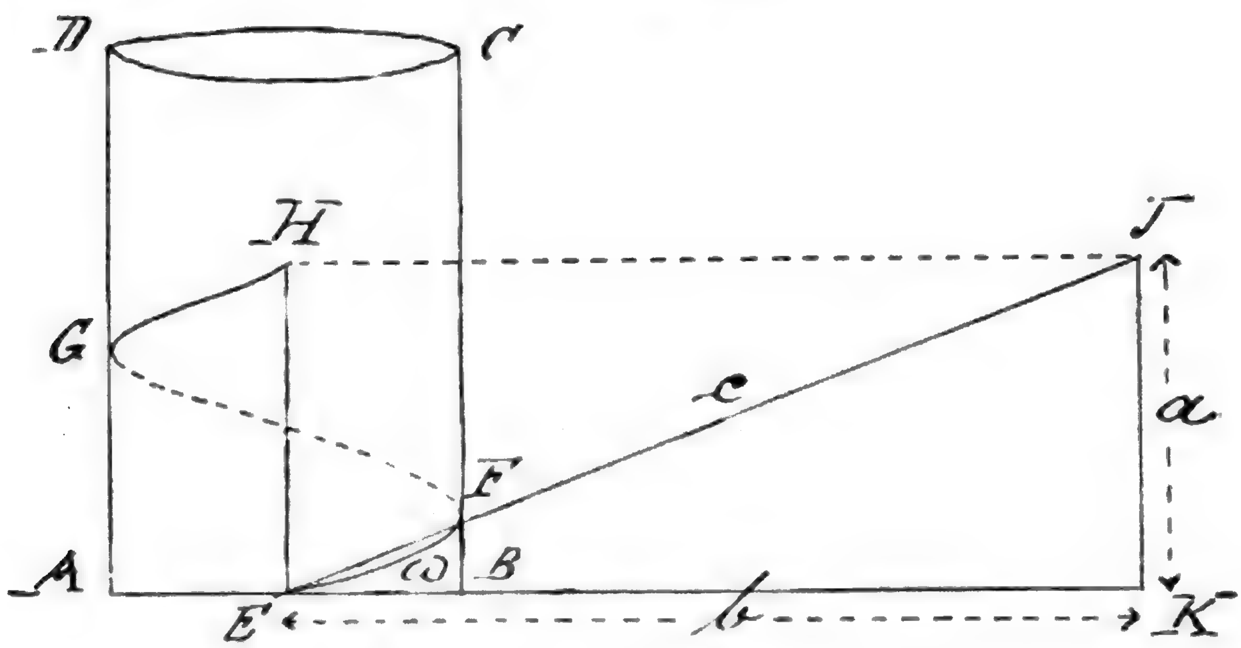
The product of force and distance gives the work.

If we imagine in a ship a water wheel of the kind described, with plane blades and constant pitch φ fitted as a propeller, and if we call the distance traveled by the wheel (neglecting slip) in an axial direction ds, in the infinitesimally small time dt, then the work per second of the infinitely small element of a blade as referred to in the previous paragraph, which is also contained in the water wheel of the vessel, is

$$dLax=dPax\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad (42)$$

Every point of the water wheel in rotating describes during the travel of the ship a cylindrical spiral, whose pitch forms an angle with the tangent of the cylinder, which we will call ω.

Fig 6



In Fig. 6 the visible surface of a cylinder is represnted by the rectangle $ABCD$, and line $EFGH$ represents the path of a spiral on the surface of this cylinder. If we imagine the path of this spiral unrolled in a straight line, then its length is given by line $EJ=c$. In the same manner we unroll the periphery of the cylinder of diameter AB in a straight line, which is represented by line $EK=b$.

The pitch of the spiral during one revolution around the cylinder is given by line $EH=KJ=a$. For every revolution of the water wheel per second the pitch is for every point of the wheel $\frac{ds}{dt}=ar$. But since we have called the angle KEJ which the spiral forms with the tangent of the cylinder ω,

$$a=b\tan\omega\,; \qquad (43)$$

therefore

$$\frac{ds}{dt}=rb\tan\omega. \qquad (44)$$

If we call the distance of the infinitesimally small surface element under consideration from the axis of rotation of the water wheel x (Fig. 4), then

$$b=2x\pi; \qquad (45)$$

therefore

$$\frac{ds}{dt}=2x\pi r \tan\omega. \qquad (46)$$

Eliminating from equation (42) value $\frac{ds}{dt}$ and substituting for it the value found in the last equation, we obtain

$$dL_{ax}=dP_{ax}2x\pi r \tan\omega, \qquad (47)$$

we found for the infinitesimally small axial pressure in this equation (32) $dP_{ax}=8mC\pi^3r^2x^3dx \sin\varphi$, and we obtain therefore from both equations for the work of the surface element under consideration in an axial direction the expression

$$dLax=16mC\pi^4r^3x^4dx \sin\varphi \tan\omega. \qquad (48)$$

This equation cannot be integrated, as the angle ω has no constant value, but is a function of b and a (Fig. 6), and can not be considered constant even for a small deviation. With increasing value of x in equation (48) the angle ω grows smaller.

The work of the tangential pressure can be ascertained in a similar way to the work of the axial pressure. The tangential pressure in doing its work passes over a longer path, the further we move on a blade from the axis of rotation. The theoretical length of the path of any point of the blade for one revolution (neglecting slip) is also equal to the length of the cylindrical spiral (Fig. 6), which, unrolled, equals line c. The length of this path equals cr for r revolutions per second. Therefore the work performed by the infinitesimally small surface element per second is

$$dL_{tg}=dP_{tg}cr. \qquad (49)$$

But as (Fig. 6)

$$c=\frac{b}{\cos\omega}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (50)$$

and as the considered surface element is equal to a distance x from the axis of rotation, it also is (equation 45) $b=2x\pi$, and therefore

$$c=\frac{2x\pi}{\cos\omega}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (51)$$

Introducing this value into equation (49) we obtain thereby

$$dL_{tg}=dP_{tg}\frac{2x\pi r}{\cos\omega}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (52)$$

We found for the tangential pressure of any infinitesimally small surface element by equation (38) $dP_{tg}=8mC\pi^3r^2x^3dx\dfrac{\sin^2\varphi}{\cos\varphi}$. Introducing this value into the former equation and noting that

$$\frac{\sin\varphi}{\cos\varphi}=\tan\varphi, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (53)$$

we obtain thus

$$dL_{tg}=16mC\pi^4r^3x^4dx\frac{\sin\varphi\tan\varphi}{\cos\omega}. \quad . \quad . \quad . \quad . \qquad (54)$$

For the same reason as already mentioned for equation (48) this equation cannot be integrated.

As line a of Fig. 6 is identical with the axial advance of the propeller (neglecting slip), it is usually denominated by the letter H. We put, therefore, $H=a$.

We found (equation 43) $a=b\tan\omega$; therefore, $H=b\tan\omega$. Furthermore (equation 45), $b=2x\pi$; and, therefore,

$$H=2x\pi\tan\omega.$$

Substituting for twice the radius x the diameter D, or $2x=D$, therefore,

$$\frac{H}{D}=\pi \tan \omega, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (55)$$

which equation is well known.

§ 5.—Tangential Losses of the Water Wheel.

If we divide equation (54) by equation (48) we obtain the relation

$$\frac{dL_{tg}}{dL_{ax}}=\frac{\tan \varphi}{\cos \omega \tan \omega}. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (56)$$

The axial and tangential work bear to each other a certain relation which is only determined by the pitch angle φ and the spiral angle ω. But as in the propulsion of a vessel only the work L_{ax} is useful, while the work L_{tg} is a loss, it will be seen that it is important in designing a screw to make the proportion between the useless work and the total work as small as possible, or that the proportion

$$\varepsilon=\frac{dL_{tg}}{dL_{a}^{x}+dL_{tg}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (57)$$

becomes a minimum.

Substituting in this equation again the values found in equations (48) and (54) for the work and expressing this in per cent.,

$$\varepsilon=\frac{100}{\frac{\cos \omega \tan \omega}{\tan \varphi}+1} \text{ per cent.};$$

or, since $\tan \omega=\frac{\sin \omega}{\cos \omega}$,

$$\varepsilon=\frac{100}{1+\frac{\sin \omega}{\tan \omega}} \text{ per cent.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (58)$$

The tangential loss in a screw propeller is, as seen from equations (56) and (58), independent of the revolutions and only determined by the angles φ and ω. This loss given in per cent. of the total work by equation (58) applies not only to a single surface element, but to the whole wheel, but for

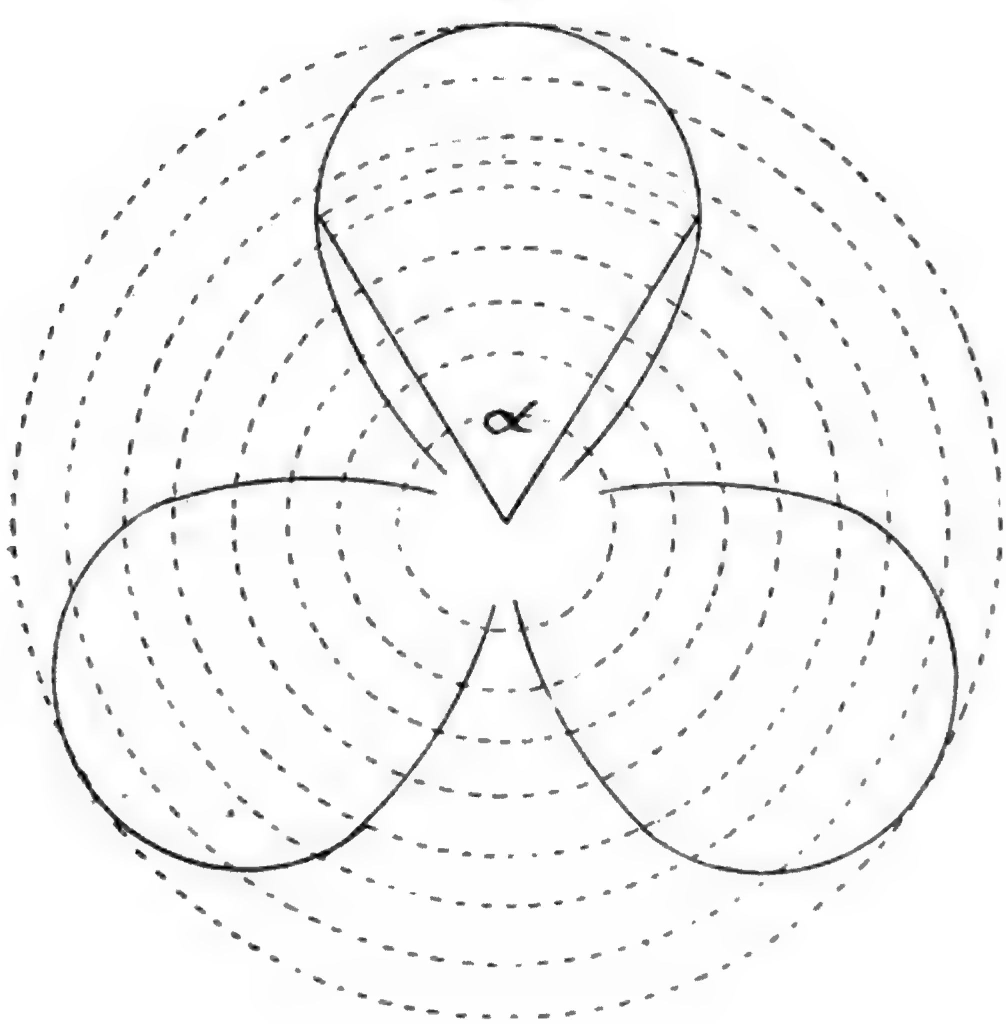
any propeller with a peripheral constant pitch angle φ and a peripheral constant spiral angle ω. To form an idea of the magnitude of the tangential losses the following table gives the values ε calculated for a few examples of the respective angles of φ and ω.

TANGENTIAL LOSS ε PER CENT.

φ	5°	10°	15°	20°	25°	30°	35°
$\omega =$ 5°	50.10	66.92	75.45	80.67	84.25	86.88	88.93
10°	33.5	50.38	60.68	67.7	72.86	76.88	80.13
15°	25.26	40.52	50.87	58.44	64.31	69.05	73.02
20°	20.37	34.01	43.93	51.55	57.69	62.80	67.18
25°	17.15	29.44	38.81	46.28	52.46	57.74	62.36
30°	14.89	26.07	34.89	42.12	48.26	53.59	58.34
35°	13.24	23.51	31.84	38.82	44.84	50.16	54.97

The table shows that the tangential loss amounts always to more than 50 per cent. when the pitch angle φ is greater than

Fig 7



the spiral angle ω. Inversely, if φ is smaller than ω the tangential loss becomes smaller than 50 per cent.; but in this case the ship cannot make the prescribed speed. Unfavorable conditions arise in both cases, either when φ is greater than ω or when φ is smaller than ω. The most advantageous degree of efficiency is obtained when φ equals ω, in which case between angle 5 degrees and angle 35 degrees a tangential loss of from 50.1 per cent. to 54.97 per cent. is unavoidable. Therefore in all our further calculations we assume $\varphi=\omega$, which transforms equation (58) into

$$\varepsilon=\frac{100}{1+\frac{\sin\varphi}{\tan\varphi}} \text{ per cent.},$$

or

$$\varepsilon=\frac{100}{1+\cos\varphi} \text{ per cent.} \quad . \quad . \quad . \quad . \quad . \quad . \quad (59)$$

The proportionate values of ε of angle φ as per equation (59) are given in the following table:

TANGENTIAL LOSS ε %.

$\varphi=\omega$	ε %	$\varphi=\omega$	ε %	$\varphi=\omega$	ε %	$\varphi=\omega$	ε %
Degrees.		*Degrees.*		*Degrees.*		*Degrees.*	
3	50.03	25	52.46	47	59.45	69	73.61
4	50.06	26	55.66	48	59.91	70	74.52
5	50.10	27	52.88	49	60.38	71	75.44
6	50.14	28	53.11	50	60.87	72	76.39
7	50.19	29	53.34	51	61.38	73	77.37
8	50.24	30	53.59	52	61.89	74	78.39
9	50.31	31	53.84	53	62.43	75	79 44
10	50.38	32	54.11	54	62.98	76	80.52
11	50.46	33	54.39	55	63.55	77	81.63
12	50.55	34	54.68	56	64.14	78	82.79
13	50.65	35	54.97	57	64.74	79	83.97
14	50.75	36	55.28	58	65.36	80	85.20
15	50.87	37	55.60	59	66.01	81	86.47
16	50.99	38	55.93	60	66.67	82	87.78
17	51.12	39	56.27	61	67.35	83	89.14
18	51.25	40	56.62	62	68.05	84	90.54
19	51.40	41	56.99	63	68.78	85	91.98
20	51.55	42	57.37	64	69.52	86	93.48
21	51.72	43	57.76	65	70.29	87	95.03
22	51.89	44	58.16	66	71.09	88	96.63
23	52.07	45	58.58	67	71.91	89	98.28
24	52.26	46	59.01	68	72.75	90	100,00

Screws with peripherally varying pitch are like those in which φ is either greater or smaller than ω; they have also a lower efficiency than screws in which φ is equal ω.

We can understand now the cause of cavitations observed in screw propellers of fast-running turbines, for if angle φ is larger than ω the vessel cannot follow as fast as the large propeller pitch travels, which latter was based upon a too large angle φ, and the available axial pressure of the screw, as well as the power of the engines, are not sufficient for such a large pitch. Furthermore, it requires time for the water to fill the void produced by the rotating screw; the rotation of the screw is too rapid for the water to follow.

§ 6.—Power Consumption of the Water Wheel.

By equation (48), which cannot be integrated, we determined the work produced by the water wheel in an axial direction.

We can ascertain the amount of this work in still another way, not only for a single surface element, but for the whole water wheel. As we have seen just now, the tangential work always bears a certain relation to the axial work, and thus we have a way to calculate the total work of a screw propeller.

Every point of the water wheel travels in axial direction over the path $\frac{ds}{dt}$; the work of the axial thrust, if a vacuum existed behind the back of the blades, is, therefore, $P_{ax}\frac{ds}{dt}$. But there is no vacuum, as water follows and exerts a pressure upon the backs of the blades.

If we call the axial component of this pressure p_{ax} then the pressure P_{ax} is reduced by that amount, and the remaining work for the axial thrust is

$$L_{ax} = (P_{ax} - p_{ax})\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad (60)$$

The motion of the water towards the backs of the blades is to fill the void produced by the rotating motion of the screw.

The direction of motion of the following water is so manifold that probably all directions in space are represented. Therefore we will assume that the water follows in three directions perpendicular to each other. We will imagine, therefore, through a point in space a right-angled tri-axial system of coördinates whose z axis runs parallel with the axis of motion of the screw; then, according to this simplified idea, one-third of all water molecules flow in the direction of the x axis, one-third in the direction of the y axis and one-third in the direction of the z axis into any void formed by the rotating water wheel. The molecules moving parallel with the x and y axes cause no change in the specific surface pressure, while the molecules moving in the direction of the z axis remain behind, and never reach the screw propeller. Therefore the pressure of the water flowing into the void behind the propeller is composed only of molecules parallel with the x and y axes, or only two-thirds of all molecules flowing after. Therefore in the last equation we have to make $p_{a_z}=\frac{2}{3}P_{az}$, which transforms it into

$$L_{az}=\tfrac{1}{3}P_{az}\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (61)$$

For the tangential work we found equation (56), in which we make $\omega=\varphi$, $L_{tg}=\dfrac{L_{az}}{\cos\varphi}$; and, therefore,

$$L_{tg}=\frac{P_{az}}{3\cos\varphi}\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (62)$$

If we name the total value of both with λ or the sum

$$\lambda=L_{az}+L_{tg} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (63)$$

the addition of both (61) and (62) gives

$$\lambda=\frac{P_{az}}{3}\left[1+\frac{1}{\cos\varphi}\right]\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad (64)$$

By equation (59) $\cos\varphi=\dfrac{100}{\varepsilon}-1$, and our equation becomes after entering this value

$$\lambda = \frac{P_{ax}}{3(1-.01\,\varepsilon)}\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (65)$$

The value of the total pressure in the direction of the axis is determined exactly by equation (37). If we enter this value in the last equation we obtain for the total work of a water wheel with constant pitch the relation

$$\lambda = .0003589\, mCT^2 \frac{\sin\varphi}{1-.01\,\varepsilon}(D_a^4 - D_i^4)\frac{ds}{dt}. \quad . \quad . \quad (66)$$

From this equation we can ascertain at once the horse-power N necessary to drive the wheel.

As $N = \frac{\lambda}{75}$, therefore

$$N = 4.785 \times 10^{-6} mCT^2 \frac{\sin\varphi}{1-.01\,\varepsilon}(D_a^4 - D_i^4)\frac{ds}{dt}. \quad . \quad (67)$$

The two equations (66) and (67) apply only within those limits in which the value ε is nearly constant, and represent the mean value of the values belonging to the diameters D_a and D_i.

§7. Determination of Thrust and Power of the Screw Propeller.

The equations given in the last paragraph were deduced under the supposition that the single blades of the respective wheel were placed close to each other (Fig. 5) and that the water could only pass through in a tangential direction but not in the direction of the axis.

If we use instead of the complete wheel only a half, quarter or n times segment of the same, then the thrust which is exerted in the axial and tangential direction will be only one-half, one-quarter or n times that of the whole wheel. The axial thrust of the same is therefore

$$P_a = nP_{ax}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (68)$$

and the tangential thrust

$$P_t = nP_{t\varphi}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (69)$$

In like manner we find the power necessary in horsepower from equation (67)

$$N = 4.785 \times 10^{-6}\, mCnT^2 \frac{\sin \varphi}{1 - .01\,\varepsilon}(D_a^4 - D_i^4)\frac{ds}{dt}. \quad . \quad (70)$$

If in the two previous equations we enter the values for the thrust from equations (37) and (40), and also observe that the water flowing in behind will reduce the active thrust to one-third that of the theoretical (see equations (60) and (61)), then we obtain

$$P_a = .0003589\ mCnT^2 \sin \varphi\,(D_a^4 - D_i^4)\,; \quad . \quad . \quad (71)$$

$$P_t = .0003589\ mCnT^2 \frac{\sin^2 \varphi}{\cos \varphi}(D_a^4 - D_i^4). \quad . \quad . \quad (72)$$

We can, as already stated in § 3, imagine each screw propeller with a constant peripheral and radially-variable pitch, divided into any number concentric water wheels with a constant peripheral and radial pitch. The blades of the propeller are thus dissected into annular segments, and each will be n times that of the whole ring or annulus.

If the axial projection of an annular segment includes the angle α from the center, and if the number of blades is Z, then

$$n = \frac{Z\alpha}{360}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (73)$$

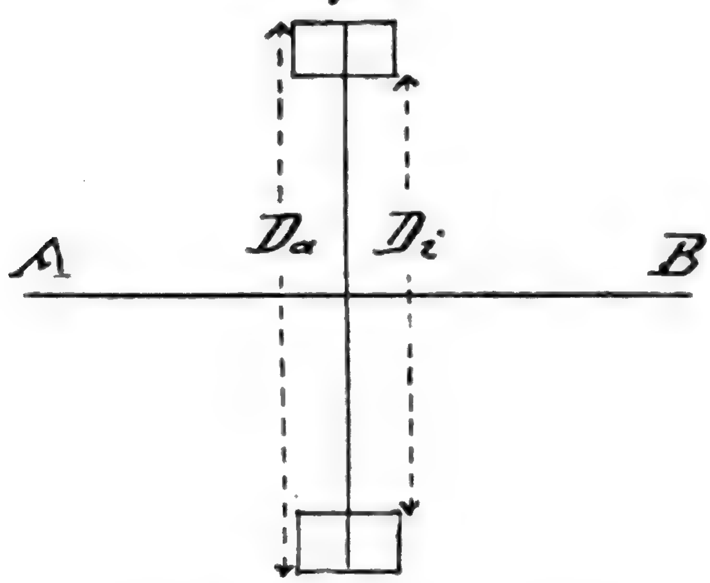
The calculation for thrust and power required by a given screw is therefore not difficult. By means of the above equations we can design a new propeller, as will be shown further on.

In deducing all the former equations it was assumed that each cross section of a blade was perpendicular to the axis of

revolution of the screw. Such a cross section is represented by Fig. 8.

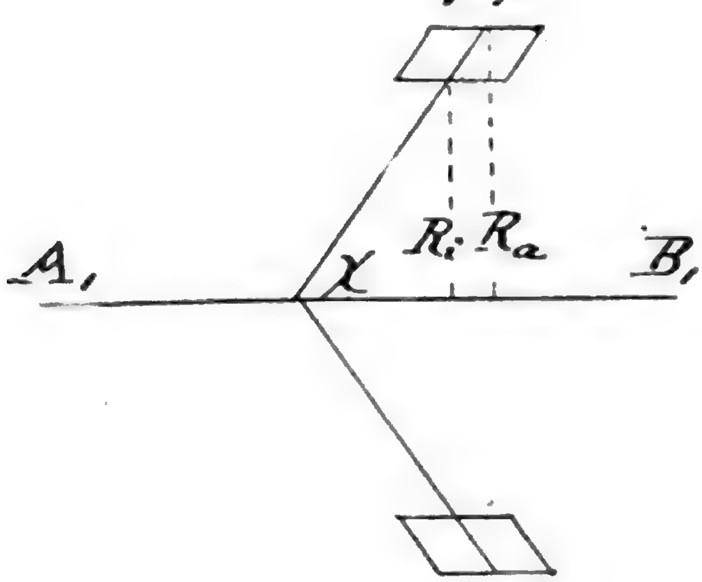
By line *AB* we show the axis of revolution of a screw propeller, and the small rectangles give the side view of one annular segment, as mentioned before. Line D_i stands for the inner and line D_a for the outer diameter of the respective ring.

Fig 8



In Fig. 8 all annular segments were arranged so that their connecting lines were perpendicular to axis *AB*, while in Fig. 9 we show an arrangement in which the connecting

Fig 9



lines of the segments form an angle with axis A_1B_1 which we will name χ. The Niki and Zeise propellers are formed in the latter manner.

If we name the vertical radii (Fig. 9) R_i and R_a, then

$$D_i=\frac{2R_i}{\sin\chi}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (74)$$

$$D_a=\frac{2R_a}{\sin\chi}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (75)$$

Entering these values in equation (70), (71) and (72), and substituting also mass m for salt water by the value of equation (23) $m=104.7$, we obtain the following relations, in which to eradicate the sum of the separate rings we put $P=\Sigma dP$; therefore

$$\Sigma dP_a=.6012\ CnT^2\frac{\sin\varphi}{\sin^4\chi}(R_a^4-R_i^4); \quad . \quad . \quad . \qquad (76)$$

$$\Sigma dP_t=.6012\ CnT^2\frac{\sin^2\varphi}{\cos\varphi\sin^4\chi}(R_a^4-R_i^4); \quad . \quad . \qquad (77)$$

$$\Sigma dN=.0127\frac{CnT^2\sin\varphi}{(1-.01\,\varepsilon)\sin^4\chi}(R_a^4-R_i^4)\frac{ds}{dt}. \quad . \qquad (78)$$

The computations for a propeller of this kind also offer no difficulties.

As the differences between the powers of the radii occur in every computation of a propeller, the table on the following page has been arranged.

It is necessary here to say something about the popular fallacy of the centrifugal action of the screw propeller. The water is forced outward partly in a tangential direction by the rotation of the screw and thereby gets out of active range of the propeller. Therefore the water cannot be set in centrifugal motion and also cannot exert a centrifugal force. There exists only a tangential force which presses the water outward.

TABLE FOR $Ra^4 - Ri^4$.

Ra	Ri	$Ra^4 - Ri^4$	Ra	Ri	$Ra^4 - Ri^4$
0.2	0.1	0.0006	1.9	1.8	2.535
0.3	0.2	0.0065	2.0	1.9	2.968
0.4	0.3	0.0175	2.1	2.0	3.448
0.5	0.4	0.0369	2.2	2.1	3.977
0.6	0.5	0.0671	2.3	2.2	4.559
0.7	0.6	0.1105	2.4	2.3	5.193
0.8	0.7	0.1695	2.5	2.4	5.886
0.9	0.8	0.2465	2.6	2.5	6.633
1.0	0.9	0.3439	2.7	2.6	7.446
1.1	1.0	0.4640	2.8	2.7	8.325
1.2	1.1	0.6096	2.9	2.8	9.263
1.3	1.2	0.7824	3.0	2.9	10.270
1.4	1.3	0 9857	3.1	3.0	11.350
1.5	1.4	1.2208	3.2	3.1	12.507
1.6	1.5	1.4912	3.3	3.2	13.733
1.7	1.6	1.7985	3.4	3.3	15.044
1.8	1.7	2.1448	3.5	3.4	16.436

§ 8.—Power Consumption of the Vessel.

Of the different resistances opposed to the motion of a vessel that of the water is the most formidable. In the second line stands the frictional resistance of the vessel in the water, while in the third line we must consider the air resistance of that part of the vessel protruding from the water.

The latter two resistances differ according to the kind of vessel; we express them, therefore, in fractions of the water resistance, or rather multiply the water resistance by the coefficient K, which shall include the addition of all resistances. We put, therefore,

$$K = \frac{W_e}{W}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (79)$$

and express thus the relation between the theoretical water resistance W and the sum of all effective resistances W_e.

The resistance of the water is equal to the area of midship section measured at the maximum cross section (Q) of the vessel multiplied by the specific pressure (p) of the water against this area. Near the surface this pressure is small, but increases rapidly with the depth of the midship section. We give this résistance, therefore, by the sum

$$W = \Sigma dQdp. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (80)$$

In connection with the former equation we obtain the value of the effective water pressure

$$W_e = K\Sigma dQdp. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (81)$$

The work required in moving a vessel when towing it is composed of the resistance W_e moved in each second through the space u, which corresponds with the effective speed of the vessel. The necessary work required for this per second, equal to the axial thrust of the screw, is expressed by the equation

$$L_a = W_e u$$

or

$$L_a = Ku\Sigma dQdp. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (82)$$

The pressure of the water is the same on both sides of the immersed midship section as long as the vessel is not moving, but after beginning to move this pressure is different, and the question is how great this pressure is either in front of the vessel or behind it. If we designate the former by dp_1 and the latter by dp_2, then the actual pressure of the water during the motion of the vessel is

$$dp = dp_1 - dp_2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (83)$$

The motion of the water behind the vessel is the same as ascertained in § 6 for the water screw.

Here again let us imagine that the molecules of water flow in three directions perpendicular to each other into the void produced by the moving vessel, and that the z axis coincides with the direction of the ship, then only the molecules from the x and y axes can reach the vessel, while the molecules from the z axis are unable to reach the ship, and therefore cannot exert a pressure either.

Our simplified idea of the suction is easier understood when considered with a vessel than with rotating propeller; both

actions result from the same cause, and therefore the dynamic effect must be the same.

Similarly to the rotating propeller we must in case of a moving vessel make $dp_2 = \frac{2}{3} dp_1$, and thereby the last equation becomes

$$dp = \tfrac{1}{3} dp_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (84)$$

Entering this value into equation (82) we thereby obtain

$$L_a = \tfrac{1}{3} K u \Sigma dQ dp_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad (85)$$

For the pressure dp_1 we substitute the height of the water column h in m. For salt water we found (equation 22) the weight of a cubic meter to be 1,027.4 kg., and, therefore, $dp_1 = 1{,}027.4\ dh$. This value entered in equation (85) makes

$$L_a = 342.45\ K u \Sigma dQ dh. \quad . \quad . \quad . \quad . \quad . \quad (86)$$

The velocity u in this equation is in meters per second, and can be ascertained in sea miles or knots from their relation. A knot (V) means the distance of 1,852 m. per hour, therefore

$$W = \frac{1{,}852 V}{3{,}600} = .5144 V. \quad . \quad . \quad . \quad . \quad . \quad (87)$$

Entering this value in the former equation, we get for the work of towing the ship the value

$$L_a = 176.17\ K V \Sigma dQ dh. \quad . \quad . \quad . \quad . \quad . \quad (88)$$

The effective speed u in equation (87) is identical with the theoretical speed as defined in § 4, $\frac{ds}{dt}$ less the retardation produced by the resistance represented by the coefficient K. The relation of this retardation to the theoretical speed is the slip of the propeller. The slip percentage is, therefore,

$$S=\frac{\left(\frac{ds}{dt}-u\right)}{\frac{ds}{dt}}\text{ per cent.}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (89)$$

and therefore,

$$u=(1-0.01\ S)\frac{ds}{dt}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (90)$$

The relation between the two velocities is nothing else than the coefficient K; for

$$W_e\,u=W\frac{ds}{dt}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (91)$$

and it follows from equation (79) that

$$K=\frac{\frac{ds}{dt}}{u}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (92)$$

This equation gives with equation (90) the value

$$K=\frac{1}{1-0.01\ S}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (93)$$

Eliminating from equation (88) quantity K, by this value we obtain

$$L_a=\frac{176.17\ V}{1-0.001\ S}\Sigma dQdh. \quad . \quad . \quad . \quad . \quad . \quad (94)$$

Referring back to equation (56), in which we assumed $\varphi=\omega$, therefore $L_t=\frac{L_a}{\cos\varphi}$, or with value of equation (94)

$$L_t=\frac{176.17\,V}{1-.01S}\times\frac{\Sigma dQdh}{\cos\varphi}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (95)$$

The total work λ is again (equation 63) $\lambda=L_a+L_t$, and after entering above values

$$\lambda=\left(1+\frac{1}{\cos\varphi}\right)\frac{176.17V}{1-.01\,S}\Sigma dQdh. \quad . \quad . \quad . \quad (96)$$

From equation (59) we obtain $\cos\varphi=\frac{100}{\varepsilon}-1$, and this value in connection with the former equation gives

$$\lambda=\frac{176.17V}{1-.01\,S}\times\frac{\Sigma dQdh}{1-.01\,\varepsilon}. \quad . \quad . \quad . \quad . \quad (97)$$

The work in effective horsepower is $N_e=\frac{\lambda}{75}$; therefore

$$N_e=\frac{2.349V}{1-.01\,S}\times\frac{\Sigma dQdh}{1-.01\,\varepsilon}. \quad . \quad . \quad . \quad . \quad (98)$$

This equation permits the immediate calculation of the required horsepower from the immersed midship section and the speed of the ship, by assuming the most probable values for the slip S and the mean tangential loss ε.

This equation (98) has no resemblance to the so-called Admiralty formula. Nothing is found in it that could justify the cube of speed in the latter.

§ 9.—Determination of Pitch Angle.

Transforming the members of equation (90), we obtain $\frac{ds}{dt}=\frac{u}{1-0.01\,S}$. Eliminating quantity u by means of equation (87), we find

$$\frac{ds}{dt}=\frac{0.5144V}{1-0.01\,S}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (99)$$

We found before the theoretical speed (equation 46) $\frac{ds}{dt}=2x\pi r\tan\omega$. From the two equations we get, therefore,

$$\tan\omega=\frac{0.2572V}{x\pi r(1-0.01\,S)}. \quad . \quad . \quad . \quad . \quad (100)$$

But (equation 36) $r=\frac{T}{60}$, and from Fig. 9, $x=\frac{R}{\sin\chi}$, if R represents the mean value between the inner and outer radius of a ring, as in Fig. 9. These two values entered into equation (100), and π given its numerical value, gives

$$\tan\omega=\frac{4.912\,V\sin\chi}{RT(1-.01\,S)}. \qquad (101)$$

As explained in § 5, the pitch angle φ must be made equal to the spiral angle ω; for this reason, the same equation applies to the pitch angle

$$\tan\varphi=\frac{4.912\,V\sin\chi}{RT(1-.01\,S)}. \qquad (102)$$

For each single ring we will have to determine the mean value of φ as per Fig. 7.

Example I.

To understand the deduced equations better, the same will be used for the calculations of a propeller. A fast steamer of 2,200 tons displacement is to have a speed V of 22 knots. The slip may be assumed, according to experimental formula, to 17 per cent.

By comparison with known steamers we will probably require 7,000—8,000 effective horsepower. We consider, therefore, that we need two turbines with $T=230$ revolutions per minute.

We determine first the pitch angle by equation (102).

$$\tan\varphi=\frac{4.912\,V\sin\chi}{RT(1-.01\,S)}.$$

For the intended screw we assume angle $\chi=90$ degrees (Fig. 9), and obtain $\tan\varphi=\frac{4.912\times22}{R\,230\times.83}=\frac{.5661}{R}$.

By means of this equation we determine the pitch angles

of the single rings of Fig. 7. Increasing the diameter of the rings by .2 m. we obtain the values in the following table. The values of ε are taken from table §5.

D_a	D_i	R (mean)	φ	ε%
0.4	0.2	0.15	75° 9′	79.5
0.6	0.4	0.25	66 10	71.2
0.8	0.6	0.35	58 17	65.6
1.0	0.8	0.45	51 31	61.6
1.2	1.0	0.55	45 50	58.9
1.4	1.2	0.65	41 3	57.0
1.6	1.4	0.75	37 3	55.6
1.8	1.6	0.85	33 40	54.6
2.0	1.8	0.95	30 47	53.8
2.2	2.0	1.05	28 20	53.2
2.4	2.2	1.15	26 12	52.7
2.6	2.4	1.25	24 22	52.3
2.8	2.6	1.35	22 45	52.0

For the calculation of the horsepower for the engine the mean value of ε can be taken at 53 per cent., as will appear later from the table for $\frac{\Sigma dN}{n}$.

The horsepower needed can be ascertained from equation (98)

$$N_e = \frac{2.349 V}{1 - .01 S} \times \frac{\Sigma dQdh}{1 - .01 \varepsilon}.$$

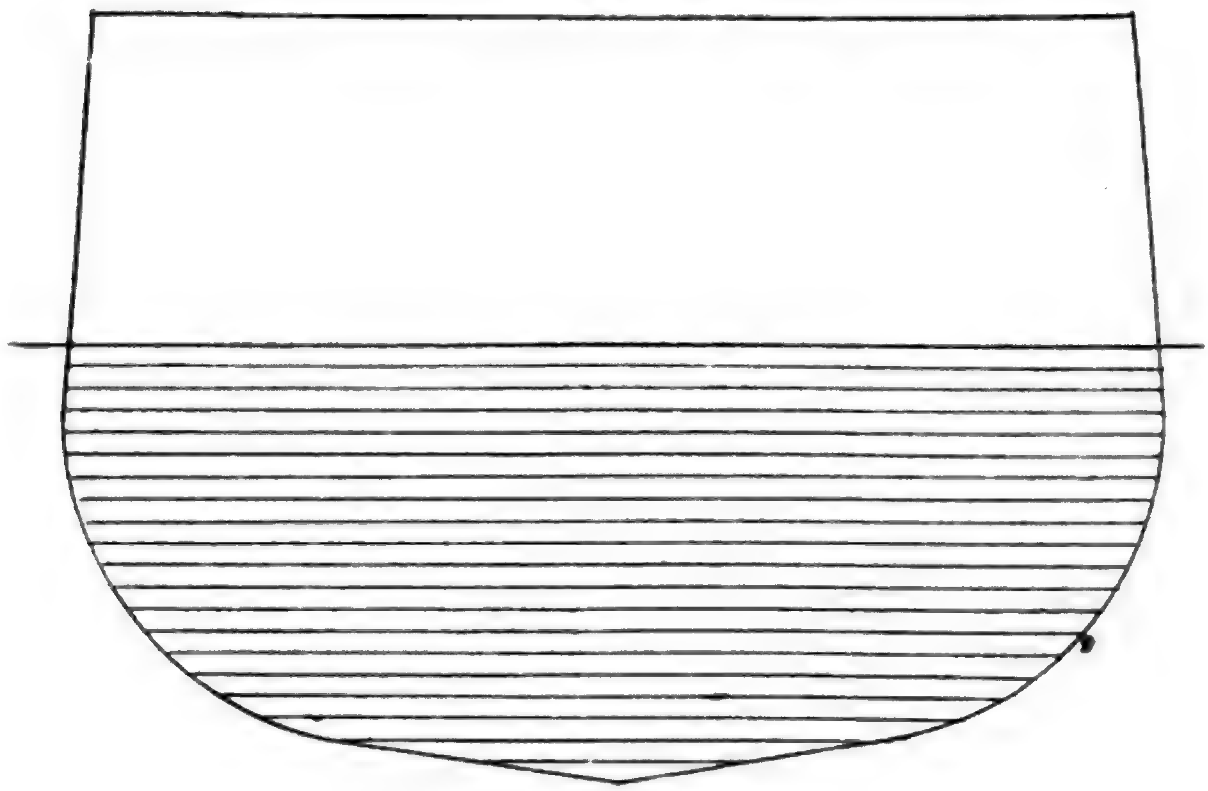
By using the three known values we have

$$N_e = \frac{2.349 \times 22 \ \Sigma dQdh}{.83 \times .47}$$

$$N_e = 132.47 \Sigma dQdh.$$

The summation $\Sigma dQdh$ represents the sum of all infinitesimally small elements of the cross section, each multiplied by the height of the column of water above it in feet. Fig. 10 represents the midship-section area to a scale of 1 to 100, and if the submerged part of the cross section is divided into strips .2 m. wide, which is sufficiently accurate, then the mean height dh of each strip is as .1, .3, .5 . . . . m.

Fig 10



From the drawing we obtain at once by measurement:

......	dQ	dh	dQdh
1st strip	10.00 × .2 = 2.00 m²	0.1	0.200
2d	10.05 × .2 = 2.01	0.3	0.603
3d	10.05 × .2 = 2.01	0.5	1.005
4th	10.00 × .2 = 2.00	0.7	1.400
5th	10.00 × .2 = 2.00	0.9	1.800
6th	9.95 × .2 = 1.99	1.1	2.189
7th	9.90 × .2 = 1.98	1.3	2.574
8th	9.80 × .2 = 1.96	1.5	2.940
9th	9.70 × .2 = 1.94	1.7	3.298
10th	9.50 × .2 = 1.90	1.9	3.610
11th	9.30 × .2 = 1.86	2.1	3.906
12th	9.00 × .2 = 1.80	2.3	4.140
13th	8.70 × .2 = 1.74	2.5	4.350
14th	8.35 × .2 = 1.67	2.7	4.509
15th	7.90 × .2 = 1.58	2.9	4.582
16th	7.40 × .2 = 1.48	3.1	4.588
17th	6.40 × .2 = 1.28	3.3	4.224
18th	5.60 × .2 = 1.12	3.5	3.920
19th	3.60 × .2 = 0.72	3.7	2.664
20th	1.00 × .2 = 0.20	3.9	0.780
	33.24 m²		57.282

Introducing this value into the last equation we obtain for the required indicated horsepower the number

$$N_e = 132.47 \times 57.282 = 7{,}588 \text{ H.P.}$$

We require, therefore, two turbines each of 3,800 H.P.

The theoretical speed can be ascertained from equation (99)

$$\frac{ds}{dt} = \frac{.5144\,V}{1 - .01\,S}$$

$$\frac{ds}{dt} = \frac{.5144 \times 22}{.83} = 13.635 \text{ m. sec.}$$

The obtained values are used to build up a propeller from equation (78)

$$\Sigma dN = .0127 \frac{CnT^2 \sin\varphi}{(1 - .01\,\varepsilon)\sin^4\chi}(R_a^4 - R_i^4)\frac{ds}{dt}$$

of as many rings until we have the required engine power of 3,800 H.P. for each of the two propellers. We have assumed $\chi = 90$ degrees and $T = 230$; the economic coefficient C for water is still an unknown quantity, but is probably not far from 0.5. It was explained in § 2 that the molecules receding from the plane meet those moving towards the plane and prevent the latter from exerting a pressure upon the same. The loss from this cause was found to amount for air to 6⅔ per cent. Water, on account of its greater density, would probably only allow one-half of the molecules moving towards the plane to reach the same, the other half is prevented from reaching the plane by the receding molecules.

To illustrate the process of calculation we assume the value of C as .60.

The above equation can be simplified by substituting the known values

$$\Sigma dN = .0127 \times .60\; n\; 230^2\, \frac{13.635 \sin\varphi}{1 - .01\,\varepsilon}(R_a^4 - R_i^4),$$

$$\Sigma dN = \frac{5{,}496\; n \sin\varphi}{1 - .01\,\varepsilon}(R_a^4 - R_i^4),$$

and, as the value for n is uncertain at present,

$$\frac{\Sigma dN}{n}=\frac{5.496 \sin \varphi}{1-.01\,\varepsilon}(R_a^4-R_i^4).$$

Reserving for the hub the value $D=.4$ m., by means of this equation and use of table of § 7 we obtain the following rings:

R_a	R_i	φ		ε %	$\frac{\Sigma dN}{n}$
0.3	0.2	66°	10′	71.2	113
0.4	0.3	58	17	65.6	238
0.5	0.4	51	31	61.6	414
0.6	0.5	45	50	58.9	644
0.7	0.6	41	3	57.0	928
0.8	0.7	37	3	55.6	1,265
0.9	0.8	33	40	54.6	1,655
1.0	0.9	30	47	53.8	2,094
1.1	1.0	28	20	53.2	2,586
1.2	1.1	26	12	52.7	3,127
1.3	1.2	24	22	52.3	3,719
1.4	1.3	22	45	52.0	4,365
					21,148

The total projected surface of all propeller rings gives 21,148 H.P. We need only 3,800, therefore

$$\frac{3,800}{21,148}\times 100=17.97 \text{ per cent.}$$

of the annular surface must be distributed for the values of n.

The value of n was by equation (73)

$$n=\frac{Z_a}{360}$$

determined, in which Z represents the number of blades. If we choose for our intended propeller three blades, then we must make

$$n=\frac{3a}{360}=\frac{a}{120}$$

and the mean value of a is

$$120 \times \frac{17.97}{100} \text{ or about 22 degrees.}$$

We now make a design as shown by Fig. 11 with this angle, and ascertain by trial suitable values for n. Thus we obtain the following values :

R_a	R_i	$\frac{\Sigma dN}{n}$	a	n	ΣdN
0.3	0.2	113	45°	0.3750	43
0.4	0.3	238	42	0.3500	83
0.5	0.4	414	39	0.3250	134
0.6	0.5	644	36	0.3000	193
0.7	0.6	928	34	0.2833	263
0.8	0.7	1,265	32	0.2667	337
0.9	0.8	1,655	30	0.2500	414
1.0	0.9	2,094	28	0.2333	489
1.1	1.0	2,586	26	0.2167	560
1.2	1.1	3,127	22	0.1833	573
1.3	1.2	3,719	17	0.1417	527
1.4	1.3	4,365	9	0.0750	327
					3,943 H.P.

The power needed for the propeller is somewhat larger than intended, and we therefore make each engine of about 3,950 H.P., especially since we did not consider in our first estimate the power needed for the hubs, which likewise as the immersed midship section, require power for their axial propulsion through the water.

The width of the blades on the arcs of the center of the rings can be determined from the drawing by dividing these arcs by cos φ, as given by the axial projection of the drawing.

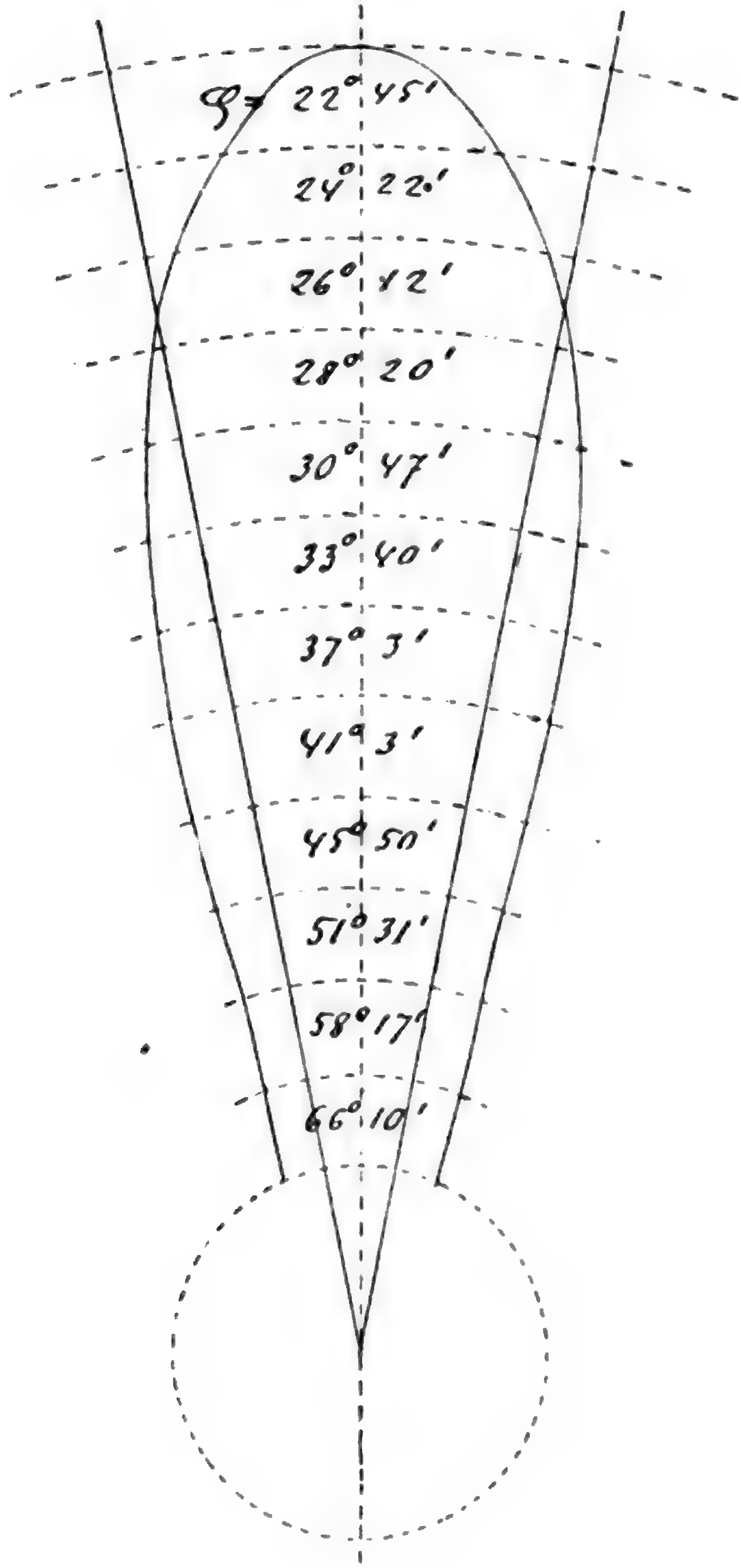
Applying our example to equation (55),

$$\frac{H}{D} = \pi \tan \varphi,$$

and using the value of the peripheral pitch, which for the middle-ring radius 1.25 is 24° 22′ and for the middle-ring radius 1.35 is 22° 45′ and for the outer-ring radius 1.4 is 21° 56′, then

$$\frac{H}{D} = \pi \tan 21° \ 56' = 1,265.$$

Fig 11



This value corresponds well with conditions of common practice. The peripheral velocity of the blades figures out to 33.72 m. sec.

Example II.

To be able to make comparisons between a turbine steamer and a piston-engine vessel we take the same steamer of 2,200 tons displacement and 22 knots speed, which we figured out before, and assume that it has two reciprocating engines making 80 revolutions. The slip must be again taken to 17 per cent. for sake of comparison.

The pitch angles by equation (102) will be

$$\tan\varphi = \frac{4.912\,V\sin\chi}{RT(1-.01\,S)}.$$

By substituting the known values we obtain

$$\tan\varphi = \frac{4.912\times 22}{R\times 80\times .83} = \frac{1.6275}{R}.$$

For the angles we get the following values:

D_a	D_i	R (mean)	φ		ε %
0.4	0.2	0.15	84°	44′	93.1
0.6	0.4	0.25	81	16	86.8
0.8	0.6	0.35	77	52	82.7
1.0	0.8	0.45	74	33	78.9
1.2	1.0	0.55	71	20	75.8
1.4	1.2	0.65	68	14	73.0
1.6	1.4	0.75	65	15	70.5
1.8	1.6	0.85	62	25	68.3
2.0	1.8	0.95	59	43	66.5
2.2	2.0	1.05	57	10	64.8
2.4	2.2	1.15	54	45	63.4
2.6	2.4	1.25	52	28	62.2
2.8	2.6	1.35	50	19	61.0
3.0	2.8	1.45	48	18	60.0
3.2	3.0	1.55	46	24	59.2
3.4	3.2	1.65	44	37	58.4
3.6	3.4	1.75	42	55	57.7
3.8	3.6	1.85	41	20	57.0
4.0	3.8	1.95	39	51	56.6
4.2	4.0	2.05	38	27	56.1
4.4	4.2	2.15	37	7	55.7

We can take the mean value of ε for the calculation of the horsepower to 58 per cent., as can be seen from the table under $\frac{\Sigma dN}{n}$.

Equation (98) gives for the necessary horsepower

$$N_e = \frac{2.349 V}{1-.01 S} \times \frac{\Sigma dQdh}{1-.01 \varepsilon},$$

the value

$$N_e = \frac{2.349 \times 22 \times 57.282}{.83 \times .42} = 8{,}491 \text{ H.P.}$$

The power consumption is considerably greater with the lower number revolutions than before. We need two engines of 4,250 H.P. each.

The theoretical speed is the same as before,

$$\frac{ds}{dt} = 13.635.$$

Building up a propeller by equation (78)

$$\Sigma dN = .0127 \frac{CnT^2 \sin\varphi}{(1-.01\,\varepsilon)\sin^4\chi}(R_a^4 - R_i^4)\frac{ds}{dt}.$$

From this we get

$$\frac{\Sigma dN}{n} = .0127 \frac{.60 \times .80^2 \times 13.635}{1-.01\,\varepsilon}\sin\varphi\,(R_a^4 - R_i^4)$$

and

$$\frac{\Sigma dN}{n} = \frac{665 \sin\varphi}{1-.01\,\varepsilon}(R_a^4 - R_i^4).$$

By means of this equation we obtain for our propeller the following values, but we must in arranging these reserve more room for the hub, on account of the lesser number of revolutions. We therefore reserve for the hub $D = .6$ m.

R_a	R_i	φ		ε %	$\frac{\Sigma dN}{n}$
0.4	0.3	77°	52′	82.7	66
0.5	0.4	74	33	78.9	112
0.6	0.5	71	20	75.8	175
0.7	0.6	68	14	73.0	253
0.8	0.7	65	15	70.5	347
0.9	0.8	62	25	68.3	458
1.0	0.9	59	43	66.5	590
1.1	1.0	57	10	64.8	737
1.2	1.1	54	45	63.4	905
1.3	1.2	52	28	62.2	1,092
1.4	1.3	50	19	61.0	1,294
1.5	1.4	48	18	60.0	1,516
1.6	1.5	46	24	59.2	1,760
1.7	1.6	44	37	58.4	2,019
1.8	1.7	42	55	57.7	2,296
1.9	1.8	41	20	57.0	2,589
2.0	1.9	39	51	56.6	2,914
2.1	2.0	38	27	56.1	3,248
					22,371

Only 4,250 of these 22,371 horsepower will be used; we must distribute, therefore,

$$\frac{4,250}{22,371} \times 100 = 19 \text{ per cent.}$$

of the annular surfaces upon the value n.

It will be unnecessary to make a drawing in this case, as this would offer nothing new, and would be similar to drawing 11, only somewhat larger.

It will be of interest to ascertain the relation of equation (55)

$$\frac{H}{D} = \pi \tan \varphi.$$

Angle φ of the extreme periphery is found to be 39° 9′; therefore

$$\frac{H}{D} = \pi \tan 39° \; 9' = 2.558,$$

a value much greater than the one obtained for the first example.

CONCLUSION.

The two examples selected can be compared only with each other, not with results from praxis, as we assumed for the constant C the haphazard value of 0.6, and this in reality is hardly sufficiently exact. As already mentioned, the value C has to be ascertained experimentally as per equation (41) before the given equations are applicable for praxis.

The value $\frac{H}{D}$ results in our second example larger than is usual in praxis, and this is a defect of the former method of calculation, that one of the most important values is fixed at the beginning, without knowing if the assumed proportion corresponds approximately to reality. If this relation is fixed at the start, then we are compelled to make the diameter unnecessarily large, to suit the accepted relation. The work of the propeller increases with its diameter. The power needed for the propulsion of the vessel is fixed. Any unnecessary increase in the diameter of the screws subtracts from the neighborhood of the hub work, which is transferred to the increase of diameter. The pitch angles near the hub must be kept so small that the water can exert no pressure in the direction of the axis.

A second very important fact is proven by theory, that the power for the vessel (equation 98) differs as the revolutions of the engine. The slower running the engine the greater must be the pitch angle φ to attain the required speed; but with an increase in the angle φ the tangential losses increase without any gain to the axial thrust, and thus is seen clearly the peculiarity of the theory. The fast-running turbines for this reason save considerable power when compared with slow-rotating reciprocating engines, as seen from our examples, where the power needed drops from 4,240 H.P. to 3,800 H.P. per engine. This fact, not before observed, also speaks for the application of turbines for ship propulsion. The section back of the hub is unavoidable, and the axial thrust of the hub requires power as well as the immersed midship section.

All the technical devices cannot change these facts, but we can choose the diameter of the hub as small as possible when designing this.

The frictional losses of the propeller through the water are contained in the constant *C*. They could not be neglected when ascertaining experimentally the value of *C*. It was therefore unnecessary to mention the frictional losses in deducing the theory, and to express these by a separate coefficient.

SOME NEGLECTED ASPECTS OF CYLINDER CONDENSATION.

The following article appeared in series in the "London Engineer."

We propose in this article to deal fully with the question, and set forth as far as possible within reasonable limits facts from which alone useful opinions can be deduced.

The point at issue, tersely stated, is this: Does or does not the multiplication of cylinders reduce what is known as "the missing quantity?" That is to say, will it be less in a compound engine than it is in a single cylinder, and less in a triple-expansion engine than it is in a compound engine? Incidentally it may be added that a reduction in the missing quantity promotes economy. We may begin by calling attention to the fact that no one has yet been able to prove by direct experiment, once for all, that the multiplication of cylinders is by itself able to reduce the missing quantity. The so-called proofs are always based on a theory of condensation, which so far as evidence goes has small basis of fact. What really takes place in an engine cylinder is extremely complex. No one knows enough about it to dogmatize.

Our first step will be to consider what takes place in single-cylinder engines. The most complete and exhaustive experiments ever undertaken with such engines were carried out by Mr. Benjamin Isherwood, Chief of the United States Navy Bureau of Steam Engineering, with the engines and boilers of a number of warships. The results were published in a thick folio volume in the year 1865. What was true of steam engines in that year is true of them now. In the preface in 1865 he wrote: "The diversity of opinion on the subject of the economy to be derived from the use of steam very expan-

sively may be chiefly attributed to our exceedingly incomplete knowledge of the physical qualities of vapors and of the forces of Nature, which has caused mathematicians to apply to steam the laws of a perfect or imaginary gas, totally ignoring its properties as matter, the forces involved, and the phenomena incident to its action; in place of which they have endowed it with purely hypothetical qualities with as much confidence as though they were ascertained facts, and proceeded to examine it as a mere problem for mathematical analysis. But in dealing practically with the subject we must include the effect of these physical properties, and ascertain in what manner they modify the mathematical determination; what are these natural forces and how far they act, and to what extent the results are affected by attending phenomena. We must not substitute fancies and loose slip-shod inferences from them for severe and extensive physical investigations of the question. The immense discrepancy between the theoretical results, inferable from Marriotte's law, and the practical results by direct experiment on the expansion of steam in steam engines proves the utter unworthiness of a metaphysical and mathematical treatment of a physical problem. To complete a refutation of the sophistical nonsense of amateurs and would-be engineers who deem *à priori* argument sounder, as it is certainly cheaper and easier, than laborious experiment, is a lesson which ought never to be lost, and should remain a perpetual warning in the future."

The veteran engineer has lived to see statements which evoked a storm of reprobation tacitly accepted as true. But the problem presented by the steam engine is still very far from being settled. The unprejudiced interested observer who has kept in touch with what has been written and said about cylinder condensation cannot escape the conviction that in this matter, as in most others, disputants have first arrived at conclusions, and then picked out from the multitude just those facts which support their theories, ignoring all others. Nor is this done with any premeditation of dishonesty. It is a policy the result of conviction, due to a lack of the sense of

proportion. It is, of course, quite unscientific, but probably unavoidable.

The first person who saw in cylinder condensation a source of avoidable waste was James Watt. The result of his cogitations was the separate condenser. Instead of putting cold water into the cylinder, he put it into an extension of the cylinder. Following this idea up, he excluded cold air from the interior of the cylinder, and substituted in his "atmospheric" engine an atmosphere of steam for one of air. From thenceforth the idea was driven home in men's minds that the cylinder should be kept as hot as possible; and the circumstance that hot steam would transfer its heat to cooler iron was accepted, not only as a fact, but as a fact of great importance. But how the transfer took place, the rate of transfer, the result of the transfer, or the factors and their bearing on the phenomena, no one troubled his head about. "The missing quantity" had not been named. No one knew that there was a missing quantity. The fact of interest for us just now is that the belief became rooted that cold iron condensed steam at a rate measured by the difference in temperature and by no other factor. Although more recently sounder views have been advanced, and it is understood that cylinder condensation is not a simple but a complex phenomenon, the original faith has never yet been eradicated; and down deep in hearts of most engineers lies the belief that difference of temperature between steam and metal is the ruling factor in settling the amount of cylinder condensation. It is nothing to the purpose that adequate experiments have demonstrated that this idea is probably entirely erroneous. It is still held as an article of faith by the multitude.

Probably the first person who attempted to treat the question scientifically was M. Combes, who, as far back as 1843, published papers in the "Acadèmie des Sciences," on the theory of the steam engine. Writing about the steam jacket in 1845, he stated very clearly the theory of initial condensation and re-evaporation. Thus, "Jackets have not for the main result the maintenance of temperature during expan-

sion; their use consists in the prevention of refrigeration of the cylinder during the exhaust period. "Various other engineers took the subject up. Among the most important investigators was De Freminville, about whom we shall have more to say. In 1851 Le Chatelier, Polonceau and Petiet took part in various discussions. That initial condensation should waste steam, and was affected in amount by the ratio of expansion, was a proposition advanced about 1855 by the late D. K. Clark, and a little later by Benjamin Isherwood. Clark's statement referred to locomotive cylinders, with which alone he concerned himself. Isherwood's had a general application. He stated that no economy could be realized by pushing expansion beyond a certain ratio, because so much steam would be condensed in the cylinder that all that could be gained by expansion and much more was lost. It is a suggestive fact that his views raised a storm of opposition. All the principles of thermodynamics were said to be violated by such a heterodox proposition, the work and theories of French engineers being ignored. So far as we are aware he was the first man who carried out on a large scale an experiment intended to test the true value of expansion. Farey, it is true, was early in the field, but his inquiries took a different turn.

Isherwood's position in the navy of the United States gave him great opportunities, and of these he availed himself. The results of his inquiries fill, as stated above, a large volume. We shall select a single set of typical experiments. They were made with the engines of the wooden war steamer *Mackinaw*, a paddle boat. She was tied up to a wharf. All the feed water was measured with minute accuracy in tanks, and the coal weighed. Indicator diagrams were taken at regular intervals, and each "run" lasted forty-eight hours. The conditions prevented the engines being worked at full power, partly because of the commotion set up in the harbor by the paddle wheels, and partly because the ship did not move. The slow speed of the engine, however, was in this case a distinct advantage, serving as it did to accentuate the phenomena of heat interchange.

The single cylinder was 58 inches diameter and 8 feet 9 inches stroke, inclined, with two double-beat poppet valves about 15 inches in diameter at each end, one for steam, the other for exhaust, worked by Stevens cam gear, giving a very smart cut-off. The engine was fitted with a Sewell's surface condenser. The boilers could supply very much more steam than was wanted. The result was that the steam was delivered free from priming to the engine. The experiments consisted in keeping the number of revolutions as nearly constant as possible, only varying the ratio of expansion. This implied that the mean pressure should be about the same, and this was got by raising the initial pressure with the higher measures of expansion. The results are given in a long table about which, among other things, Isherwood says: "On line 60 will be found the per cent. of the steam evaporated in the boilers which remained condensed in the cylinder at the end of the stroke of the piston by other causes than the production of power. Now, it must be distinctly borne in mind that these quantities do not express the whole condensation which took place in the cylinder. A portion, and probably a large portion of the condensation during the first part of the stroke was re-evaporated during the last part under the continuously lessening pressure caused by the steam after it was cut off; consequently the shorter the steam was cut off the greater would be the re-evaporation, so that the quantities on line 60 do not express correctly proportionally the condensations due to other causes than the development of the power; these condensations being, in fact, much larger proportionally for the higher measure of expansion than shown on line 60. Great, therefore, as a condensation of 37.82 per cent. appears when cutting off at .21, the real condensation must have been far greater. It will be observed that these condensations increase with the measure of expansion with which the steam is used, rising from 7.46 per cent. when it is cut off at 0.70 of the stroke of the piston at the commencement, to 37.82 per cent. when it was cut off at 0.21 of the stroke of the piston." The experiments with the *Mackinaw* were repeated with several other

ships. The interest of the passage which we have quoted lies in the fact that, to all intents and purposes, for the first time it told the engineering world the quantitative story of initial condensation and re-evaporation, as ascertained by a practical experiment carried out on a large scale.

We reproduce "line 60."

	Cut off at			
	0.70	0.56	0.38	0.21
Per cent. of water evaporated in the boiler not accounted for by the indicator..........	7.46	11.43	21.82	37.82

The first impression conveyed by "line 60" is that the cylinder condensed $37.82 - 7.46 = 30.36$ per cent. more steam when steam was cut off at 0.21 of the stroke than when the cut-off took place at 7.46. This is just one of the mistakes which are made most often by writers and speakers dealing with engine economy. It would only have been true if the conditions had been identical, which they were not. All the evaporation figures are given in thousands of pounds. The pounds of water pumped into the boiler when the cut-off was at 0.70 were 523,682; when the cut-off was at 0.21 they were 398,578. Now, 7.46 per cent. of 523,000 pounds is 39,000 pounds, and that was the weight of steam missing with the late cut-off. In like manner, 37.82 per cent. of 398,000 pounds is 150,444 pounds. If we compare the percentages as given in "line 60," it would appear that the condensation was more than five times as great with the cut-off at 0.21 as it was at 0.70; in reality it was less than four-fold.

We may now try to trace out what took place in the cylinder.

To the quantities given in line 60 must be added the percentage required for the performance of work. About this Isherwood wrote: "There is another condensation of steam in the cylinder independent of and additional to that which is effected by the variable temperature of its surfaces, namely, that which is due to the production of work. This condensation, however, differs materially from that already described, in that it does not take place upon, and is not affected by, the

cylinder surfaces. It takes place uniformly throughout the whole mass of steam in the cylinder, and the resulting water, in the form of extremely fine mist or fog, is held in whole or in part suspended by the steam. If any of the water is precipitated on the metallic surfaces it will be re-evaporated during the exhaust stroke of the piston at the expense of the fuel, and no work will be obtained from it."

To this statement exception may be taken. Some additional facts have been obtained since Isherwood wrote, and he has overlooked one of the neglected points. He shows that in the case of the *Mackinaw* with the cut-off at 0.21 the liquefaction reached 7.84 per cent., and cutting off at 0.70 it was 8.72. The total missing quantity, therefore, was in the first case 45.66 per cent., and in the latter 16.18 per cent. During expansion it is commonly assumed, and the indicator seems to prove it, that re-evaporation goes on continually. We shall show further on that this is by no means certain. Are we to assume that the work done by expanding steam does not produce liquefaction, or that liquefaction can proceed *pari passu* with re-evaporation? We have here a point which has never received adequate consideration. Let us assume that it cannot; then the whole of the liquefaction due to the performance of work must take place during the admission period. But many persons, Sir Alexander Kennedy among the number, hold that no work whatever is done in the cylinder during the admission period. It is all done in the boiler. The steam simply constitutes a sort of plug or extension of the piston pushed out by the boiler, and any liquefaction must take place in the boiler—that is to say, if liquefaction is conceivable at all under the circumstances. We see no reason to dispute the soundness of this conclusion. But then we are left on the horns of the dilemma already stated—either no liquefaction or no re-evaporation can occur, or else they must go on together. We shall return presently to the phenomena of re-evaporation. But before doing so it is necessary to consider those of condensation and liquefaction more fully. In unjacketed cylinders, such as that of the en-

gine of the *Mackinaw*, it is well known that on the whole the curve of pressure agrees within a very small percentage with Marriotte's hyperbola. Isherwood writes: "An analysis of a vast number of indicator diagrams from well-conditioned engines of many types and proportions, using steam with varying measures of expansion, and fitted with great diversity of valve gear, shows the total mean pressure to be almost exactly that which is due to Marriotte's law, namely, the pressures are invariably as the spaces, including in the latter the contents of the clearance and steam pumps; and this agreement is not affected by the steam being in the saturated or superheated condition, and with any degree of superheating. In the case of saturated steam the curve falls at first a little too rapidly, and at last not quite rapidly enough. The reverse is the case with superheated steam; when saturated steam is used the pressure at the end of the stroke of the piston is very little greater than is due to Marriotte's law, and when superheated steam is used it is very little less."

The agreement with Marriotte's law has always been a matter of common knowledge, and it has always been regarded as a coincidence. But there must be some reason for this coincidence. With adiabatic expansion even steam gas cannot follow Marriott's law, if work is being done. In the case of saturated steam we must believe that the water provided by initial condensation supplies so much heat that we have isothermal expansion, the whole of the heat used up in the performance of work being thus supplied. We have here a point which has never received the consideration it deserves. The practical fact cannot be disputed. The explanation that it is a mere coincidence repeated thousands of times is wholly unscientific. Nor will it do to say that the curves are not precisely Marriotte's. That they should be nearly Marriotte's at all under so many varying conditions is very remarkable. It is well known that physicists are by no means agreed as to what the curve of steam expanding and doing work ought theoretically to be. Rankine writes:* "From the results of

* "A Manual of the Steam Engine and other Prime Mover."

numerical calculations of the co-ordinates of adiabatic curves for steam it has been deduced by trial that for such pressures as usually occur in the working of steam engines the relations between these co-ordinates is approximately expressed by the following statement: The pressure varies nearly as the reciprocal of the tenth power of the ninth root of the space occupied; that is to say, in symbols $p \propto a^{-\frac{10}{9}}$ nearly." It suffices here to mention this. The reader can pursue the question of the theoretical curve in various treatises on the steam engine. The fact of the so-called coincidence remains, and claims an explanation which so far it has not received.

We now proceed to consider what probably took place in the cylinder of the *Mackinaw*. All the conditions were as favorable as can be conceived to the waste of steam. The pressure was low; the ratio of expansion small; the piston speed only about 110 feet per minute, the revolutions per minute being under 7. The total missing quantity at the end of the stroke is 45.66 per cent. when the cut-off took place at 0.21 and 16.18 per cent. when it took place at 0.70. In the first case 7.84 per cent. was liquefied—by calculation—in the performance of work; in the second case 8.72 per cent.

Let us take the cut-off at 0.21 of the stroke. When the admission valve opened steam entered. Of this 37.82 per cent. was condensed, ostensibly when the steam valve was open. During the earlier phases of expansion a small proportion may have been turned to water, but there is no reason to think that this substantially affects what follows. We have shown already that the actual weight condensed amounted to 150,444 pounds in forty-eight hours, or 3,135 pounds per hour, omitting fractions. The total condensing surface available we cannot give precisely, but it could not have exceeded 140 square feet, in which are included two piston faces, two cylinder covers, and about one-half the cylinder walls. This gives condensation at the rate of, in round numbers, 22 pounds of steam per square foot per hour; the absolute pressure, 53 pounds; the exhaust pressure, 1.84 pounds; the temperatures,

284.6 degrees and 120 degrees; the difference, omitting fractions, 164 degrees.

It will be seen that under these conditions apparently considerably more than one-third of all the steam made by the boilers was condensed by 140 square feet of cast iron. But the surface condenser contained no less than 2,293 square feet. The temperature of the injection water was 44.5 degrees, and that of the steam at the moment the exhaust valve opened 213 degrees; the difference, omitting fractions, was 168 degrees. The cylinder as a condenser was transcendently more efficient than the surface condenser itself. Carefully lagged, always hot, we find, nevertheless, that 140 square feet could do 37 per cent. of the whole work done by 2,293 square feet of refrigerating surface kept constantly wet with cold water. No doubt the condenser was larger than was necessary, because the engine was not working up to its full power. After every allowance is made, however, the difference in cooling efficiency is astonishing.

It may be objected that the conditions prevailing were not the same in the condenser and the cylinder. The point deserves examination. The steam was delivered to the cylinder intermittently; condensation was followed by re-evaporation. But in just the same way, and at just the same rate, steam was delivered to the condenser; the fluctuations of temperature were just the same in it that they were in the cylinder in point of time. The only difference is that there was perhaps no re-evaporation from the metallic surfaces in the condenser. Are we to assume then that in re-evaporation and not in condensation lies the key to the whole problem of initial condensation—that in this re-evaporation lies some subtle power of abstracting heat and cooling down the cylinder metal which has no parallel in a surface condenser? Again, what shall be said of the evaporative efficiency of the cylinder as compared with that of a boiler? Where shall we find a boiler which will evaporate 22 pounds of water per square foot per hour? and that with a temperature of 2,500 degrees at one side of a plate and 300 degrees at the other.

The two boilers of the *Mackinaw* had each 2,500 square feet of heating surface, or 5,000 square feet in all. If they had been as efficient as the cylinder, they would have produced 110,000 pounds of steam per hour; sufficient at 30 pounds per I.H.P. per hour for over 3,600 H.P., or about four times the actual maximum power that could be got out of the engine.

It is not remarkable, we think, that some able engineers have refused to accept such a statement as that made above as true, and have cast about for other ways of accounting for the missing quantity, or have sought explanations of the astonishing frigorific and evaporative powers of cylinder metal.

Among those who have investigated this question, the most recent and most important writers are Messrs. Callendar and Nicholson. They refuse to believe that an adequate interchange of heat can take place between the steam and the cylinder, and attribute the missing quantity mainly to leakage past the sliding valves of an engine. We say sliding, not necessarily slide valve—thus a Corliss valve is a sliding valve, but not a slide valve—such a valve, they say, may be quite tight when at rest, but leaks when in motion. These gentlemen set themselves to measure the range of temperature at various depths within the metal of a cylinder, and satisfied themselves that the surface temperature, instead of following that of the steam, only went through a very small range. Thus with their experimental engine at 70 revolutions per minute, whilst the steam temperatures varied between 335 degrees Fahrenheit and 212 degrees Fahrenheit, a range of 123 degrees, the temperature of the inside surface of the metal only varied 7 degrees. From this it was easy to show that only a small percentage of the missing quantity is due to condensation. Their explanation is, as we have said, that the difference is leakage past the slide valve. Furthermore, they deduced that the rate of condensation of steam, instead of being infinite, is limited. They hold that the rate at which steam condenses on a metallic surface is propor-

tional to the difference in temperature between the steam and the metal, and may be represented by the following equation: B.T.U. exchanged per second per square foot $= 0.74\,(T - \theta)$, where $T =$ temperature of steam and $\theta =$ temperature of metal in degrees Fahrenheit.

Messrs. Callendar and Nicholson do not stand alone. Everyone who has considered the subject admits that something remains to be explained.

Unfortunately for the leakage theory, the missing quantity appears to be quite independent of slide valves. The engine of the *Mackinaw* had poppet valves; they are at rest on their seats when closed. It is the easiest thing in the world to make sure that they are practically steamtight, and this Isherwood did.

Some experimenters have satisfied themselves that in compound and triple engines conditions may exist under which the cylinder walls are never dry. It is necessary to call attention to certain obvious facts. No matter what occurs in a cylinder, the occurrences must be cyclical. That is to say, begun and ended in one double stroke of the piston. Whatever the boiler transfers to the cylinder, whether as steam or water, the cylinder will hand on to the condenser. The only difference will be due to the effects of external radiation and conduction and leakage, if any, into the air, and performance of work. This means simply that if steam is condensed during the steam stroke, it must be evaporated during the exhaust. If it is not, then heat would accumulate in the cylinder until condensation ceased, as, in point of fact, happens when an engine is first started. On the other hand, re-evaporation, if in excess of condensation, would cool down the cylinder so much that it could no longer go on. Priming will in effect pass through the engine unaffected. The accumulation of water, therefore, in a cylinder from what is known as initial condensation ought to be physically impossible. Even this appears, however, to require qualification.

The cycle then seems to admit of being stated thus: During admission, part of the steam is condensed, none of it is

liquefied by the performance of work. During the expansion period evaporation goes on simultaneously with liquefaction. During exhaust all the remaining water in the cylinder is evaporated until such time as the exhaust port closes. Then compression begins, and the pressure will continue to rise unless there is water present in sufficient quantity, when liquefaction will begin again, the action then being precisely as though the water absorbed the steam. Then steam is admitted, and the cycle is repeated. It is exceptional, however, to find any water lying in well-made engines properly worked. It is easily drained off.

There are very great difficulties in the way of accepting this account of what goes on in a cylinder. That difficulties exist is proved by the number of hypotheses advanced to explain recognized phenomena.

The first is that the condensation seems, as we have shown above, to be out of all proportion to the ostensible agencies bringing it about, while it is so capricious in its magnitude that it is simply impossible to prepare any formulæ by which it can be calculated. The presence of a spoonful of water in the cylinder will enormously augment the missing quantity. A little oil will diminish it. We can understand that water may in some way promote condensation, but how can it promote the re-evaporation which must also go on? It is too often forgotten that every factor must work both ways. Whatever agency facilitates condensation must in precisely the same degree promote re-evaporation. A jacket will check condensation, and help re-evaporation. It cannot at the same time promote condensation. Conversely, cooling a cylinder outside will promote condensation, but it will certainly not favor re-evaporation. The double or reversible action to which we refer appears to be a point which has not received sufficient consideration.

Then we have liquefaction, which must not be confounded with condensation. Liquefaction is due to the transfer of heat into work. The assumption is that water in the condition of mist results, as stated by Isherwood. To this it may

be answered that it is impossible to prove the truth of the theory by direct experiment. It has long since been proved conclusively that water vapor cannot take the form of mist unless dust is present. How can dust exist inside a cylinder? No one has the smallest idea of the way in which the transformation takes place.

Two views which have obtained some credence may be stated here. The first is that what is called initial condensation is the result of the movement of the steam—the transfer of part of its pressure energy into kinetic energy—that of flow. The collision of the steam with the piston is in effect very similar to its collision with the blades of a turbine—only to a great disadvantage; and that if this will not suffice as an explanation, then that, in some way not understood, the mere impact of steam on an opposing surface will upset its equilibrium and bring about condensation. No proof can be given of this, unless the statement that, no matter how many "separators" steam is passed through, water will be found in them all, can be regarded as a demonstration. The second and far more plausible view is that no liquefaction takes place, because the water of condensation in the cylinder can supply all the heat that is necessary. The fact that it is almost impossible to obtain an indicator diagram the curve of which certainly shows the drop due to performance of work may be taken as supporting this theory.

Before we deal with the phenomenon of re-evaporation it is well to consider for a moment what takes place in a compound engine. Theory may be ruled out of court. It would be waste of time to reason as to what ought to happen. We have only to deal with what does happen.

Numbers of experiments have been carried out, both at sea and on land, with compound and triple-expansion engines. The disheartening thing about these trials is their incoherence. No two engines will give the same results, and it has so far passed the wit of man to explain why. Qualitative facts agree always; quantitative facts only by chance. Thus it is always true that, other things being equal, the larger the

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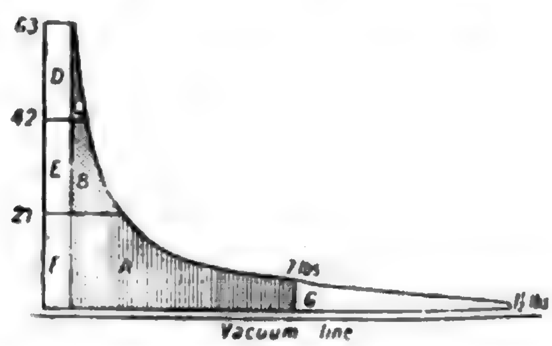
range of expansion the more economical will the engine be. But there certainty ends. We cannot trace any invariable relations between the ratio of expansion and the consumption of steam, which can be reduced to weight used per indicated horsepower per hour.

We can take figures anywhere at haphazard to prove this. Compare for the moment the compound engines of the *Colchester*, cited by our correspondent, Mr. Hide, in our impression for May 1st, and that of the *Mackinaw*. The missing quantity in the *Colchester* is 47.3 per cent. against 45.66 per cent. for the engine of the *Mackinaw;* and it must not be forgotten that the *Mackinaw's* was developing only a percentage of her power. Even the *Meteor*, with triple-expansion engines jacketed, lost 24.7 per cent. We have already shown what a well-designed simple engine can do. Here we have a comparison between excellent compound and triple engines and a simple engine working under every conceivable disadvantage. What has the heat trap done here? Major English, R. E., a most careful experimenter, after a prolonged painstaking inquiry, stated years ago that he had completely failed to trace any definite relations between range of cylinder temperature and initial condensation. Elaborate experiments carried out with a number of engines in the United States, which were worked alternately with and without condensers, brought out the remarkable fact that the missing quantity was greater when the exhaust went into the air than when it went into the condenser, although the range of cylinder temperature was, of course, much less.

Those who hold the heat-trap theory as an article of faith very often cling to it because they fail to see why the multiplication of cylinders should promote economy on any other ground. They are so far right in that theoretically the number of stages into which the expansion of a gas is divided has no effect on the ultimate result. The compound engine is, nevertheless, more efficient than the single-cylinder engine, and they attribute the saving in fuel to a diminution in the weight of the missing quantity. We have here one of the ne-

glected points about cylinder condensation which this article is intended to bring into prominence. It is that the introduction of a second cylinder alters the working *régime* radically. The compound engine in daily life is nearly always worked at a higher pressure and ratio of expansion than the single-cylinder engine. In the few cases in which it is not, the introduction of the second cylinder effects no economy. We are dealing now with the steam engine as it is found in mills and ships, not as it is met with in college laboratories. Nothing, perhaps, can better illustrate what we mean than the work done by Macnaught in Lancashire and Yorkshire some sixty or seventy years ago.



Let the accompanying diagram represent the energy in 1 pound of steam, with a pressure of 63 pounds. The total quantity of heat expended in making it, with feed water at 60 degrees, is 1,172 B.T.U. The final condenser pressure is 1½ pounds. Let the engine have a single cylinder working with 21 pounds steam, expanded three times; the terminal pressure is 7 pounds. F represents the full pressure part of the stroke, A the expansion part, F + A represent the work got out of the steam. Now Macnaught found beam engines driving cotton and woolen mills all over Lancashire and Yorkshire working with pressures as low as 21 pounds. In practice it requires no more coal to make steam of 63 pounds than it does to make steam of 21 pounds pressure. Knowing this, Macnaught doubled the boiler pressure to 42 pounds and put in a second cylinder. This was sometimes fixed between the beam center frames and the crank, so that the piston had about half the stroke of the original piston. In other cases

a horizontal or an inclined cylinder was used, a new and larger crank pin being provided. In this way he utilized all that portion of the diagram marked E B, and greatly reduced the fuel bill. If we add a third cylinder working at 63 pounds we utilize D C. We have in effect three steam engines instead of one, and these three require no more steam than F A did. This is the whole essence of compounding in a nutshell. It is the simplest and crudest way of stating the case. The statement is incomplete, but it is not inaccurate. Macnaught achieved a great success. We believe that there are "Macnaughted" engines still running in out-of-the-way corners of Manchester and Lancashire.

It is, of course, obvious that the whole of the work of expansion might be done in a single cylinder; but it would not be good engineering. The compounding and tripling and quadrupling of cylinders is done to reduce stresses and to get better turning moments. The truth of the idea that the reduction in the range of temperature in each cylinder is a factor in producing economy has never yet been demonstrated, while the evidence that it is not is exceedingly strong. Our contention can be best put into the form of a definite proposition.

The multiple-cylinder steam engine of commerce is more economical than the single-cylinder engine of commerce, because it works at a higher pressure and with larger ratios of expansion.

In a sense all this has been a digression. But it was essential to clear the ground, and we may now return to the consideration of the phenomena of condensation.

It is not very easy to get examples of tests of large triple-expansion engines which are not complicated by the use of jackets. We select, however, a triple-expansion rotative pumping engine at Milwaukee, which at one time attracted a great deal of attention because of its high economy. It was put to work about 1894. It was constructed by the E. P. Allis Company from the designs of Mr. Reynolds. The contract stipulated for 18,000,000 gallons per 24 hours, delivered

under a head of 160 feet, the guaranteed duty being 125,000,-000 of foot-pounds per 100 pounds of anthracite. This engine was reported upon two or three times.

The most complete trial was carried out by Professor Thurston, and made the subject of a very long and elaborate paper which he read before the American Society of Mechanical Engineers in 1894. The only points of interest for us are the cylinder condensation and re-evaporation. The vertical cylinders are 28 inches + 48 inches + 74 inches × 60 inches. Revolutions per minute, 20; speed of piston, 200 feet per minute; steam pressure at engine, 128 pounds; vacuum, 13.75 pounds. The cylinders are all jacketed, the pistons working in liners. The steam in the first two jackets is at boiler pressure, in the last at 34 pounds. The clearance is very small. There are two intermediate receivers heated by boiler steam. It will be seen that we have here all the conditions most favorable to a reduction in the missing quantity. It is difficult indeed to see why condensation should take place at all; for the jacketing is so complete that it includes the valve chests. Yet "the measurements of the indicator diagrams as originally practiced by Hirn show a progressive increase in the internal condensation of from 12 per cent. in the first and 14 per cent. in the intermediate cylinder to 18 per cent. in the low-pressure cylinder." A combined diagram is given, from which we find that at the moment when the admission valve closed 11.9 per cent. of the steam was missing. The percentage condensed in the jackets is nowhere directly given, but in the course of the discussion which followed the reading of the paper it was said to be 9.25 per cent. apparently for the high-pressure cylinder alone; but this is not certain. Nothing was said of the receiver jackets or those of the other cylinders; but we have no reason to doubt that here in this most elaborately heated engine the missing quantity reached 28 per cent. Professor Thurston deducts a percentage for work done, and goes on:—"It thus appears that the jackets reduced initial condensation, which, in an unjacketed engine of this size and action, would, as

known by experience, be at least 25 per cent., and possibly 30 per cent., to 12 per cent. initially, and to a final 18 per cent.—which would have been 30 or 40—of 20 per cent."—Here we have a man of high reputation, and much experience, conceding with one stroke of the pen that there is nothing in the heat-trap theory, in so far as it means reduced condensation as a result of reduced range of temperature. We may add that his calculations as to the percentage liquefied are wrong, because he has assumed that work was done in the cylinder during the admission period, which, as we have shown in our last impression, is not the fact, the conversion of heat into work occurring not in the cylinder but in the boilers, the true initial condensation—not liquefaction—being about 12 per cent. for a cylinder jacketed with steam at boiler pressure. If space were available we could adduce the story of dozens of tests, all of which go to show that there is no traceable relation between the number of cylinders and the missing quantity, and all pointing to the probability, if not the certainty, that steam is missing not only because of an interchange of heat between steam and cast iron, but for some other reason the nature of which has yet to be settled. We may conclude this line of argument by considering what would take place in theory and in practice in a perfectly non-conducting cylinder.

If heat were not supplied to the steam, that is to say, if adiabatic expansion went on while work was being done, liquefaction would take place. The amount would represent the whole missing quantity. This is thermodynamic theory. There is, however, reason to believe that it does not represent what would really take place. We cannot have a non-conducting cylinder, but we can diminish the conducting power of a cylinder. Thus, for example, the insides of the covers and the piston faces can be coated with lead. The specific heat of cast iron is about 0.13, while that of lead is little over 0.03. The conducting power of lead is as 18 is to 56 for cast iron. It will be seen, therefore, that the heat would have to travel much further into the substance of a lead cylinder, and

that it would be much longer in getting through, than under normal conditions. Consequently a material advantage would be gained by substituting lead for cast iron. Accordingly the experiment has been tried both in this country and the United States, but no advantage appears to have been gained. Wherever we turn we find ourselves confronted with a contradiction of some kind. Thus, although, as we have shown from Isherwood's experiments, condensation and re-evaporation are very large, and although, therefore, it is natural enough to assume that range of temperature must be an important factor, no permanent relation of any kind can be proved to exist between range of temperature in a cylinder and the amount of the missing quantity. So perplexing are the facts that it is not remarkable that many engineers casting about for the solution of the difficulty have suggested that the missing quantity is due to the presence of water in the cylinder; that, in a word, it is water and not cast iron that brings about initial condensation. This view was taken by Clausius and Zeuner, and opposed by Hirn. A very sharp controversy took place in 1887. It does not appear that any particular result followed—no converts were made. Incidentally the question of superheating came in, and it is worth notice that Hirn stated that in his experiments, no matter how highly his steam was superheated, it invariably lost the whole of the superheat the moment it entered the cylinder, a fact which he used to show how instantaneous is the transfer of heat from even gaseous steam to a metal. This supplies another contradiction, for it is well known that great difficulty is incurred in raising the temperature of any gas by passing it through heated iron pipes.

But Hirn and Zeuner and Clausius were by no means the first to see that the effect of water in a cylinder deserved careful consideration. We have already referred to De Freminville, who seems to have been one of the first, if not the first, to consider the effect of water. We take the following statement of his views from a paper on "The Theory of the Steam Jacket," read in 1894 by Professor Thurston:

"Suppose the cylinder to contain a certain quantity of water, and let us see what occurs during a single revolution of the crank, neglecting, for the present, the influence of the metallic interior surface of the cylinder, which we will suppose perfectly inert.

"Let n represent the number of cubic inches of water contained in the cylinder at the end of the stroke.

"T= the temperature of that water, which will evidently be that of the entering steam.

"t'= the temperature of the condenser.

"H=the total heat of steam.

"While the cylinder is in communication with the condenser, the mass of water n, in presence of a vapor of low tension and temperature, commences boiling, and a quantity x is evaporated, leaving the water remaining at the temperature t' of the condenser; this remaining mass being $n-x$.

"Then we have the equation

$$nT=(n-x)t'+xH;\ x=n\left(\frac{T-t'}{H-t'}\right). \quad . \quad . \quad (1)$$

"There then remains in the cylinder a mass of water $n-x$ at the temperature t', and at that instant steam enters again; coming in contact with the comparatively cold water, it condenses to a certain amount x', making the temperature of the resulting mass $n-x+x'$ equal again to T, and we obtain the following equation of the quantities of heat:

$$(n-x+x')\,T=(n-x)t'+x'H;$$

$$x'=(n-x)\frac{T-t'}{H-T}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

But

$$n-x=x\left(\frac{H-T}{T-t'}\right)^*$$

$$\therefore x'=x\frac{H-T}{T-t'}\cdot\frac{T-t'}{H-T}=x; \quad . \quad . \quad . \quad . \quad . \quad (3)$$

* Since from (1) $n(T-t')=x(H-t')$,
adding $-x(T-t')=-x(T-t')$;
$(n-x)(T-t')=x(H-T)$.

consequently, the quantity of steam condensed, on entrance into the cylinder, is equal to the quantity vaporized during the exhaust, and the amount in the cylinder remains unchanged.

"If, in the expression $x = x'$, we make $T = 230$ degrees, $t' = 122$ degrees, $H = 1,170$ degrees, we obtain $x = n \times \frac{108}{1,058} = 0.1\,n$; the vapor condensed at each stroke of piston and thrown into the condenser, without having produced its full useful effect, is equal to one-tenth of the quantity of water in the cylinder."*

De Freminville computes the amount of this action in an engine of 55-inch diameter of cylinder and of equal stroke, and working at the low pressures and expansions then customary, and finds that a layer of water 0.2 inch in thickness, covering the bottom of the cylinder—the engine had vertical cylinders—having an area of 2,375 square inches, would measure 7 liters (6.5 quarts, 1.63 gallons); one-tenth of this quantity, as above, would be equal in weight to the whole quantity of steam supplied per stroke of engine, and the consumption of steam would thus be made double that of the engine with a non-conducting cylinder, and with no moisture present. He concludes: "It may be seen from this fact how important is the accumulation of water, however slight in quantity, in the interior of the cylinder." Assuming this amount of water, just taken, to be uniformly spread over cylinder head, piston and cylinder proper, it would be but 0.032 inch in thickness over an area of 96.93 square feet; which, as he says, "may be compared to the mist on the window pane." "Such a deposit may occur wherever the temperature of the cylinder is slightly below that of the entering steam; and this is always the case, in regular working, unless special precautions are taken." He then goes on to show that this layer of mist may transfer heat to and from the metal of the cylinder, and thus intensify the effect of cylinder condensation. "This being the situation, when the steam

*"Cours de Machines à Vapeur," Paris, 1862, p. 121.

again enters the cylinder it is condensed, yielding its heat to the metal again until all the cooled mass and the water of condensation are restored to the temperature of the entering steam. This effect would not be produced if the metallic surfaces of the cylinder could be maintained at the temperature of the entering steam." He then goes on to explain how this may be done by a jacket. On this showing any difference in temperature, however small, will produce a deposit of moisture in the cylinder; and if water is the main factor in augmenting the missing quantity, then we see that mere difference in range of temperature may have a very small effect. A trifling difference will do as much mischief as a great one.

It is worth while to consider two factors which are neglected. The first, already twice referred to, is the circumstance that no external work is done during the admission period,* and, as a consequence, that when the admission-port valve closes, the steam is dry so far as liquefaction is concerned. All the conversion of heat into work which takes place inside a cylinder goes on during expansion. We quote the following passages from a communication sent by Mr. Isherwood in 1889 to the Institution of Civil Engineers, being his contribution to a discussion which followed the reading of a paper by the late Mr. Willans, on non-condensing engine trials, because it is in effect a development of the views of Clausius and Zeuner, in that it proposes to explain why water in a cylinder should be so potent for mischief. In effect it means that dry steam will not readily exchange heat with cast iron. Wet steam will. The performance of work makes steam wet. Therefore, condensation is augmented by expansion. It will be seen that, according to De Fremenville and Zeuner, the interchange takes place mainly between steam and water. According to Isherwood, the water only serves to promote the exchange between steam and cast iron: "When steam was

* Mr. Parsons has stated that the exhaust steam from his turbines is dry ("Proceedings of the Institution of Civil Engineers," vol. 96). This seems incompatible with the performance of external work.

used expansively in a cylinder, the cylinder condensation was the aggregate of two entirely distinct quantities; one, the condensation due to the work done by the expanding steam, the other, the condensation due to the metallic surfaces of the cylinder, including those of the piston and steam passages, and to the changes of their temperature. The last quantity, however, was almost wholly caused by and bore a direct relation to the first, without which it could have existed to but a very trifling degree. Hence, of the difference between the weight of steam evaporated in the boiler according to tank measurement, and the weight existing in the cylinder at any point of the expansion portion of the stroke of the piston according to indicator measurement, only the part which remained after deducting the condensation due to the power developed by the expanding steam should be credited to the effect produced by the surfaces of the cylinder and their changes of temperature. Wet steam—that was, steam from every molecule of which some *vis viva* had been taken, or, in other words, steam that had been subjected to partial molecular condensation as opposed to complete mass condensation—had the property of conducting heat in a marked degree, while dry steam, on the contrary, was practically almost destitute of this property. This kind of wet steam could only be produced by using steam expansively, and the more expansively it was used the wetter it was, and the wetter it was the greater was its power of conducting heat. From the foregoing it would be perceived how indispensable, in the analysis of steam-engine performance, was the knowledge of the weight of steam condensed in the cylinder to furnish the heat transmuted into the work of the expanding steam. It was the key to the solution of the problem of steam condensation in working cylinders, no rationale of which could be given by any hypothesis that ignored it. Unexpanded steam was dry and transparent in a working cylinder throughout the whole stroke of the piston, suffering scarcely any condensation, no matter how great the difference between the temperature of the entering steam and the temperature of the

exhaust or back pressure. Expanded steam was wet and opaque, and wet and opaque in proportion the measure of its expansion. The surfaces of the cylinder and their changes of temperature were involved in the problem of cylinder condensation only by means of the wetness of the expanding steam, the finely divided water of condensation forming a connection between those surfaces and the interior of the body or mass of the steam in the cylinder, and enabling this mass in function of its capacity as well as of its external surface to abstract heat from the metal surfaces. This action was entirely different from that of steam not doing work condensed on the surface of a cooler mass of metal. In such a case the steam was dry, and only the layer in direct contact with the surface was affected, the condensation being wholly superficial and proportional to the area of the surface and the difference of the temperatures. But in the case of cylinder condensation when the steam was used expansively, the condensation was not only at the superficies of the mass of steam, but was throughout the entire mass, every molecule of which, so to speak, was simultaneously acted upon by the metallic surfaces of the cylinder. Hence, the enormous quantity of condensation which comparatively small surfaces of cylinder were enabled to effect. If any cylinder not doing work, the exhaust port being kept closed and the piston stationary, was put in communication with the steam room of a boiler, the metal of the cylinder being maintained at the temperature of the exhaust steam, by the external application of cold, the condensation of the steam would be entirely superficial, and the water of condensation would be deposited upon the metallic surfaces, and would be insignificant in quantity compared with that which would be obtained from the same cylinder in operation, using the steam expansively between the same temperatures. This great difference of effect denoted an equally great difference of cause in the two cases, which depended on the fact that in the one case the condensation was of dry steam at the surface of contact, while in the other case

the condensation was of wet steam molecularly throughout the mass."

It may be taken as proved by long extended experience that water in a cylinder is always inimical to economy. How are we to reconcile all this on any theory of metallic heat interchange with Professor Cotterill's assertion that water acts the part of a non-conductor. He calculates that the surface film of moisture does not weigh over 0.01 pound per square foot; that it has a thickness of about 0.02 inch, which gives an obstructive effect, impeding the passage of heat into the iron and out of it equal to that of a film of iron 0.02 inch thick. From this it would appear that water in a cylinder ought to promote economy instead of reducing it.

We have now, we think, shown (1) that so far as evidence is available, the multiplication of cylinders and the reduction of the range of temperature in each has little effect in determining the amount of the missing quantity; (2) that an error is very commonly made in laying down theoretical steam curves for comparison with real indicator diagrams, in that it is taken for granted that work is done during the admission part of the stroke, whereas it is done in the boiler; and (3) that even in practice as good a result can be had from a single cylinder as from a good triple-expansion marine engine.

Although writers on the theory of the steam engine seldom agree with each other, on one point they are united, namely, that water in the cylinder is highly mischievous, precisely how no one can prove. We have shown that the presence of quite an insignificant weight of water may be made to account for the whole missing quantity; but it has to be proved that the small weight of water can be present just at the time it is wanted. One party maintains that evaporation is never complete—that, in other words, at no period during the cycle represented by a single revolution is the cylinder thoroughly dry. The opponents of this view hold that the cylinder must be dried, or else heat would gradually accumulate in the metal.

We have dealt with the theories of condensation; we have now to consider those of evaporation. Let us suppose that in a given engine steam is expanded threefold, that the stroke is 3 feet, and that steam is cut off when the piston has moved 1 foot from the end. Clearance is assumed not to exist. Condensation takes place through one-third of the steam stroke, evaporation through the expansion period, or 2 feet, and throughout the whole of the exhaust stroke, or 3 feet. The time during which condensation can take place is one-sixth of a revolution, and evaporation can take place in five-sixths of a revolution. All the phenomena occur in very minute spaces of time; admission may last less than the tenth of a second; evaporation can then have half a second, and so on. With high-speed engines these times are, of course, still smaller. It is one of the arguments against metallic condensation that there is not sufficient time available for the passage of heat to permit any sensible thickness of the metal to be heated or cooled. Let us further suppose that water has been deposited on the cylinder surfaces; this water is hot. What follows requires careful consideration, because it appears to be quite a neglected factor in the question.

When heated water has the pressure on it reduced, a portion of it *will convert itself* into steam. We have put three words into italics because they state a special truth. The quantity that will resume the condition of steam in this way is readily calculated by well-known formulae, which need not be given here. This re-evaporation would take place in a non-conducting cylinder, but in that case the re-evaporation could not be complete. In a conducting cylinder it can only be complete if the metal gives back to the steam what it received. It is quietly assumed that the evaporating water has some subtle power of extracting heat from the cylinder walls and cooling them down; and we have heard the action supposed to take place explained on the theory of the porous earthen jars used to cool water in the tropics, with which it has nothing to do. If the inside of a cylinder were dry, it could not cool down during the exhaust stroke—at least, to

any appreciable extent—because dry steam is a very bad abstractor of heat. Reduction in the temperature of the cylinder walls can only go on while the film of water in contact with them is colder than they are; and the cooling of the water is brought about by the fact that the temperature of steam, and water in contact with that steam, is settled by the pressure and by nothing else. It is an internal affair, and has nothing whatever to do with the temperature of surroundings. Thus we have only to lower the pressure to reduce the temperature, without introducing any external cold agency whatever. In a word, it is the pressure during exhaust that determines the percentage of re-evaporation. A familiar example, often quoted, is the cryophorus, by which a liquid can be frozen in one glass globe by keeping another several feet away from it, but united by a tube, in a mixture of snow and salt. Furthermore, if we have hot water under pressure and suddenly release that pressure, a percentage of the water—say, 20 per cent.—will at once flash explosively into steam. It is in this way that the violence of boiler explosions is explained. Now, although the mysterious change from the liquid to the fluid condition can take place with the rapidity of a lightning flash, it by no means follows that heat can be transferred from iron to water with the same rapidity. It would be fair, then, to suppose that the moment an exhaust port opened a percentage of the water present would be converted into steam by what may be termed the automatic action of heated water when relieved by pressure, while the remainder would dry off gradually as it obtained heat from the metal. It is somewhat disconcerting, therefore, to find that the whole of the water disappears in a fraction of time too small to be noted even in engines running at comparatively slow speeds.

Mr. Donkin, some years before his death, made many attempts to learn by actual inspection what goes on inside a steam engine. To this end he constructed small engines with glass cylinders, but the cylinders cracked and could not be used without serious risk, in spite of wire guards. Then he

fitted to the compound beam engine in his Bermondsey works a "steam revealer," a species of clear-glass bottle which could be put in communication with the clearance space at the top of the cylinder. The phenomena have often been described. When the steam valve opened water was deposited as dew on the glass. When the valve closed the deposit ceased. When the exhaust valve opened the glass cleared instantly. If a transfer of heat took place from the glass to the water it must have been at a rate which is not contemplated by such calculations as those of Dr. Mellanby, given in his paper on steam jacketing, read in 1905 before the Institution of Mechanical Engineers at Liège. His calculations are based on the rate of transfer per minute. Mr. Royds has very properly pointed out in our correspondence columns that this may be very misleading. The right method of reckoning is to take the actual time during each stroke that condensation can go on.

The letter from Mr. Royds which appears in our correspondence columns contains nothing to which we take exception. He believes that valve leakage to a considerable extent takes place in all engines under all circumstances. He is not without followers. But he will do well to remember that by far the greater number of engineers refuse to admit that any appreciable leakage in first-class engines goes on. On this point we would refer him to the "Transactions" of the Institution of Mechanical Engineers for 1905, Vol. II, where he will find the discussion which followed on the first report of the Steam Engine Research Committee. According to Messrs. Nicolson and Callendar, the valves pass water, not steam, and the steam seems to be condensed by flowing through minute leaks. But no satisfactory attempt has been made by any one to show what becomes of the "latent" heat of the condensed steam in this case. There is the further difficulty that in compound and triple-expansion engines the percentage of the missing quantity fluctuates, sometimes being considerably less in the intermediate than it is in the high-pressure cylinder. It is not easy to see how the leakage water handed on to this second cylinder should be converted

into steam in it. We have not quoted "Mr. Isherwood's old-time statements as evidence against valve leakage," but simply to show how the action of water may be explained on one theory.

It will be seen, then, that if the cylinder is dry when the admission port opens, initial condensation cannot be due to water. But in that case the transfer of heat from steam to cast iron must take place at a rate which sets calculations at defiance. Again, in order that the cylinder may be dry, evaporation must be caused by a scarcely less rapid transfer of heat from the metal to the water. All this goes, of course, to support the views of Clausius and Zeuner. Indeed, if we suppose that metal and steam and water cannot interchange heat to all intents and purposes instantaneously, we are compelled to postulate either that water lies permanently in the cylinder, the surfaces being always wet, or else that there is some other agency at work to account for the missing quantity, the nature of which agency has yet to be ascertained. A plausible way of reconciling facts is to take it for granted that boiler steam is always wet. But this is very difficult to prove. Another explanation has already been referred to; it is that the first steam which enters "loses its life;" not because it is cooled down, but dynamically from shock, and as the effect of loss of energy by collision with inelastic walls.* In this way water is produced sufficient in quantity to account for further condensation. It is right to add here that in Donkin's experiments a small quantity of water always remained in the bottles. This seems to be due to loss of heat by external radiation and conduction. Professor Unwin has given a very ingenious explanation of the phenomena.

Whenever steam is condensed it is said to surrender its lat-

* One of the patent difficulties about the molecular-battery-pressure theory of gases is that it presupposes perfectly elastic molecules, which can collide not only with each other, but with the surface of the vessel on whose parts they exert pressure, without loss of energy. Were it otherwise, the pressure in a gas cylinder must gradually diminish unless the gas received heat continuously. But the metal walls of a compressed gas cylinder are not perfectly elastic. Yet the pressure does not fall. To get over the difficulty Sir Oliver Lodge has framed the hypothesis that the gas molecules never come in contact with the metal at all, but with a lining of the ether, which being perfectly elastic there is no loss of energy.

ent heat. Now, this is a very misleading statement unless it is used with caution. There is no such thing as latent heat. All the heat in steam is expressed by its temperature measured by its weight. The "latent heat" represents so much work done in making steam out of water, and this can be caused to reappear either as work of another kind or as "sensible" heat. In a steam cylinder a portion does work on the piston and a portion reappears as heat. The first accounts for liquefaction, the second goes to the condenser. But of the precise nature of the processes going on or the phenomena involved nothing is known with any certainty; nor will anything be known until an inquiry into the nature of steam, the method of its production, and the way in which it parts with its dynamic energy has been carried out.

Reference has been made more than once in our columns to the curious theory of C. Wye Williams, which is in effect that water cannot be heated at all. To accept this view it is necessary to believe that water molecules have no temperature. When heat is applied it is converted into kinetic energy, and steam is produced which is immediately diffused through the mass of water, just as CO_2 is in "soda water," and it is this steam which affects the thermometer. According to this theory the water lying in a cylinder would simply absorb steam at one pressure, as a sponge does water, and give it out again at another pressure. This is precisely what appears to take place in engine cylinders during the compression stroke if much water is present. When a bubble of steam is made to pass down one leg of a glass U tube it will become smaller and smaller until it may quite disappear. As it passes the bend and begins to rise again on the other side it will again form, growing larger and larger until it reaches the surface. The difference of pressure at the top and bottom of the tube is only a few ounces. What becomes of the latent heat when the bubble vanishes? The absorption theory was surrounded with difficulties when Williams first broached it. But many of these disappear in the light of recent researches into the

nature of matter. The position of the theory of the steam engine may best be set forth by an allegory.

Once upon a time a king decided that he would have a pillar erected to his honor, and he called upon all his subjects to contribute stones and gold and iron and all things needful. And his subjects elected certain wise men and entrusted them with the work, and each of these men studied the subject and made calculations, and used up the whole Greek alphabet and much more; and after a time they met and proceeded to build the pillar, and lo! what each man contributed was very good, and nicely designed, and in many ways quite clever. But when they came to put the parts together, behold! none of them would fit, or if, peradventure, two did, they were left out in the cold by all the others, and to this day the pillar remains unbuilt.

On the 13th of March, 1888—that is, a little more than twenty years ago—Mr. P. W. Willans read a paper before the Institution of Civil Engineers on "Economy Trials of a Non-condensing Engine, Simple, Compound and Triple." No more noteworthy paper has ever been read before an engineering society. It occupies, with the memorable discussion which followed it, 196 closely-printed octavo pages of the "Transactions." The trials were remarkable for their completeness and the scientific accuracy with which they were carried out. But the discussion which followed was even more remarkable, because nearly every eminent engineer, professor of engineering or physicist at home or abroad took part in it. We have already quoted from its pages. The prominent feature of the whole was that no two of the speakers agreed, save on a few general principles. No sooner was one proposition advanced as a matter of fact than it was contradicted by another bit of fact from the lips of a different speaker. It was not as though there were two theories—two sets of men in opposition. There were almost as many theories as speakers; and all, be it remembered, first-class men—men of experience, men who advanced nothing that they had not satisfied themselves was true. The whole literature of the subject

may be said to be summed up in this little volume, and in the last twenty years we have made not the smallest advance towards formulating a true theory of the steam engine as an explanation of what goes on inside it. The discussion on Willans' paper represents all that is known today.

The permanent practical present-day fact is that in superheating and the reduction of clearance space lies the source of economy. All improvements in the reciprocating engine must have for their object the exclusion of water from the cylinder and the reduction of clearance space. There is no valid reason why this last should not be as small as it is in ammonia compressors. It has already been brought down to 1½ per cent. It does not appear that any advantage worth the extra first cost is to be had from excessive pressures or temperatures, and it seems likely that the best commercial results can be had from mill or electric generating engines, with 140 pounds pressure in the cylinder at cut-off, and 8 pounds when the exhaust opens, and a superheat of 150 degrees at the engine. The engine to be a cross-compound. Something between 9 pounds and 10 pounds of steam per indicated horsepower may be expected from a thoroughly well made, well designed engine working within these limits. By carrying 220 pounds at sea, and using quadruple engines, a result equivalent to about 11 pounds or 12 pounds of steam per I.H.P. may be had. But the same result might be had with much lower pressures in a triple engine with a superheat of 100 degrees Fahrenheit at the engine and efficient drainage for the receivers.

We have endeavored in writing this article to be impartial. Our object has been to direct attention to some of the many facts and expressions of opinion which are neglected in the present day by those who write about the steam engine. We have advanced no theory of our own ; we have have done no more than suggest. But, judging from the remarkable things in the way of condensation and liquefaction that apparently go on in cylinders, it seems that a field of inquiry remains unexplored which may contain matters of value. The certainty

is that if only steam was a more stable fluid than it is, it would be in like proportion more economically efficient; and it is in the art of imparting this stability that the promise and potency of steam lies, and not in the mere raising of boiler pressure, or the multiplication of cylinders.

S. S. *TENYO MARU.*

TURBINE MACHINERY AND OIL-BURNING BOILERS.

REPORT BY ENSIGN W. S. ANDERSON, U. S. N.

While taking passage, June 11, 1908, from Kobe to Yokkaichi, Japan, on the S. S. *Tenyo Maru*, I was allowed to inspect the turbine propelling machinery and oil-burning boilers of that vessel.

The following information was kindly given to me by the Chief Engineer of the *Tenyo Maru*, Mr. A. H. Seaver, an American, from the State of New York. There are nine other engineer officers, all Japanese.

The *Tenyo Maru* is a triple-screw turbine steamer belonging to the Toyo Kisen Kaisha (Oriental Steamship Co.). Displacement, 21,000 tons, gross 14,000, net 7,265. It was completed in 1908 by the Mitsu Bishi Dock Yard and Engine Works, Nagasaki, Japan.

The turbines, of the Parsons' type, were built by the Parsons Marine Steam Turbine Co., Wallsend, England, in 1907.

There are three 12-inch hollow-steel shafts, each carrying one propeller; pitch, 105 inches; diameter, 115 inches. The central shaft carries one turbine, the high-pressure one. Each wing shaft carries two turbines, one to go ahead, one to go astern, both in the same casing, with a common exhaust. Just outboard and slightly above each wing turbine casing is a surface condenser of the ordinary type, but having also an augmenter.

Steam can be admitted to the central high-pressure turbine, to both the wing ahead turbines and to both the wing astern turbines. Ordinarily, when going ahead, high pres-

sure steam is admitted to the central high-pressure turbine only, passing from that to the wing ahead turbines and from each of those through that wing exhaust to its condenser. In case it is desired to stop, shutting off the steam from this central turbine by one valve stops the machinery. In case it is desired then to maneuver, high-pressure steam may be admitted directly to either the ahead or astern turbines on either or both sides. As the wing turbines on one side have a common exhaust, no exhaust valves have to be fitted and only steam valves need be manipulated.

There is an emergency governor of the ordinary centrifugal type which acts when 330 revolutions are exceeded. A normal number of revolutions for about 20 knots speed is about 303. The normal number of revolutions astern at full speed is probably about 200.

The oil for lubricating the turbines is used over and over again, being circulated by a pump under a pressure of ten pounds, the oil passing through a water cooler.

The steam pressure is balanced by the upper part of the thrust bearing; the propeller thrust by the lower part of the thrust bearing; therefore, if in equilibrium, there should be no thrust on the thrust bearing.

Longitudinal adjustment is provided for by a micrometer gauge in contact with a dummy piston, and also the longitudinal adjustment may be obtained by calipers at a point on the turbine shaft.

Ordinary steam packing is employed.

The blades are of special bronze.

The principal overhauling necessary at the end of a run is to overhaul the bearings.

The total I.H.P. which can be developed ahead is about 20,000; astern, about 7,000. This is measured by means of a torsion meter.

The condenser vacuum is increased by having an augmenter assisting the air pump. Additional suction is obtained by the use of a jet of steam, upon the principle of an

injector in a pipe, connected at one end to the bottom of the condenser and at the other end to the air-pump suction.

While under way at a speed of about 16 knots, the engine-room indicators were read as follows: Revolutions, port, 240; starboard, 240; central, 240. Boiler steam, 165 pounds. High-pressure steam, 90 pounds. Port low-pressure steam, 12 pounds. Starboard low-pressure steam, 12 pounds. Port astern, 27-inch vacuum. Starboard astern, 26.5-inch vacuum. Port condenser, 26.7-inch vacuum. Starboard condenser, 26.8-inch vacuum. Feed-water heater, 2 pounds less than atmospheric. It is thus seen that boiler steam is wire drawn considerably, dropping from 165 to 90. The wing astern turbines should, of course, show the same amount of vacuum as the condensers. It is possible to use as much as 160 pounds steam pressure at the high-pressure turbine.

The engine room is roomy and the temperature not excessive. There was no vibration worth mentioning.

An excellent book on this turbine is the following: "The Marine Steam Turbine," written by J. W. Sothern, published by Whittaker & Co., Paternoster's Square, London, in 1906, price 2*s.* 6*d.* net.

Boilers.—The *Tenyo Maru* has thirteen single-ended oil-burning Scotch boilers. Nine were in use when going at 16 knots speed. They were completed in 1908 by the Mitsu Bishi Dock Yard and Engine Works, Nagasaki. The oil-burning attachment was built by Lassöe-Lovekin (Oil-Burning Co.?), Brooklyn, N. Y., in 1907.

The front end of the furnaces, the lower third of the furnaces and the back end of the combustion chamber are lined with fire brick. Each boiler has four furnaces and each furnace has one oil-burning nozzle. Residuals is burned, at present Borneo oil being used. 1.2 pounds of oil is burned per I.H.P. There were seven men on watch as a firing force, effecting a considerable reduction in this force over that necessary in case coal had been used. This vessel carries 3,500 tons of oil and no coal. The tanks are open to the atmosphere. Everything is kept clean about the tanks and there

are facilities for sucking out gases from the surface of the tanks. The oil burned is heated to a temperature of 140 degrees Fahrenheit and is under a pressure of 20 pounds per square inch. Compressed air, under a pressure of 3½ inches of mercury, enters the nozzle with it. One nozzle consumes 400 pounds of oil per hour. One pound of oil converts 14 or 15 pounds of water into steam from and at 212 degrees Fahrenheit.

As the relative heating efficiencies of coal and oil is about as 4 to 7, and as oil can be bought more cheaply than coal, and also requires a smaller firing force, there is a very considerable economy in the use of the oil. Some figures on the cost of petroleum fuel can be obtained from a pamphlet entitled "Petroleum in California," published by the California State Mining Bureau, Ferry Building, San Francisco, California.

One point about marine turbines which should appeal to the naval constructor is the fact that they do not require the head room that reciprocating engines require, and they could, therefore, be gotten under a lower protective deck and with less congestion of machinery in the engine room. Also, in case of ramming or sudden stopping there are no exposed moving parts into which men or spare parts might be projected.

SUBMARINE MINES AND MINING.

BY MAJOR RICHMOND P. DAVIS, COAST ARTILLERY CORPS, U. S. ARMY.

The terms "submarine mine" and "torpedo" have been used somewhat loosely; they should have the significance given below.

A submarine mine consists of a case containing a charge of explosive and appliances for firing it, fixed in position beneath the surface of the water. A torpedo consists of a case containing a charge of explosive and appliances for firing it and propelling it through the water. The submarine mine is thus purely defensive in character while the torpedo is defensive-offensive. However, the records show much more damage to vessels by mines than by torpedoes.

Mines may be classified as mechanical and electrical, depending upon the method of firing; as ground and buoyant, depending upon whether the case is placed on the bottom or held in position near the surface of the water.

Mechanical mines have all the firing apparatus in the case, and when planted are dangerous to friend and foe, as they will fire when struck by a passing vessel. Once planted there is no indication of their whereabouts or condition, therefore their employment is a question of expediency. That they are wonderfully effective in destroying both friend and enemy is shown by the experience of the Russians in the late Russo-Japanese War.

The favored method used for firing mechanical mines are as follows:

1. A glass tube containing sulphuric acid is placed so that it will be broken by the jar when the mine is struck and

allow the acid to come in contact with potassium chlorate; the heat of reaction will cause the explosion of the charge.

2. A pistol and ball are arranged so that the ball will be thrown against the pistol trigger when the mine is struck and thus cause a shot to be fired into the charge, exploding it.

Mechanical mines may be planted very readily and are very cheap, hence their extensive use. The operation is very dangerous, and a Russian mine planter was blown up at the very beginning of the late war in the East by one of her own mines. The dangers incident to planting, to raising these mines after the war is over, the chance of shifting from the position at which planted, of breaking from their moorings and drifting in the path of neutral vessels or to the high seas, make their use very precarious. Laws should be enacted to prevent their indiscriminate use and thus eliminate the dangers to neutral shipping which may be passing through the theater of war operations.

Electrical mines may be classified either as controllable or non-controllable. Those of the former class may be rendered dangerous or inert at the will of an operator on the shore, and may be tested at any time. The defense is thus familiar at all times with the whereabouts and condition of every mine, and the mine field is a known and reliable element of the defense. The non-controllable electrical mines are fired by means of a firing battery which is thrown overboard after the planting vessel has anchored the mine and drawn off to a safe distance. After the battery is thrown overboard this electrical mine is to all intents and purposes a mechanical one, and its use has resulted solely from the danger incident to planting the latter. This mine has a further advantage in that it would be rendered inert in all probability if torn from its moorings.

Metallic-mine cases are used universally and are spherical, cylindro-spherical and conical in shape. The first type is the best, as it exposes the same surface to the tide currents, whatever be the submergence, gives great buoyancy and is easy to handle. The case may be made in a single piece, the hemi-

spheres being pressed and then welded along the equator; or it may be in two pieces and prepared for service by placing a rubber gasket between the hemispheres and clamping on the equatorial lip. The former is the more reliable type, but the latter is necessary when the mine cases have to be kept aboard ship and the storage space reduced, therefore, to a minimum. If the case is in a single piece, as shown in Fig. 1, the charge and firing mechanism are inserted through a hole called the loading hole, and this is closed by means of a plug through which the electric conductor passes to convey the current to the fuse; stuffing boxes are provided to prevent leakage. The explosive must be made up of a number of small packages which may be inserted through a hole not more than five or six inches in diameter.

With the type consisting of two hemispheres clamped together when the mine is to be planted, the charge is assembled in a single piece and placed in one of the hemispheres and the other then clamped on. As in the preceding instance, the electric conductor for the firing battery must come out through a stuffing box. Experience shows that the mine cases in a single piece can be kept down with much greater certainty against leakage than those composed of two pieces.

The mine should be moored so that it is just far enough beneath the surface at low water not to be seen. The tidal current has a depressing effect, hence for harbors with swift tides great buoyancy is necessary. Experiment has been made to prevent this extra submergence by an attachment against which the current would work and develop a force contrary to that of the current against the mine case proper. However, the best method is to obtain greater buoyancy by increasing the size of the case as shown in Fig. 2. Experiments have been made with the loading hole and mooring attachment on the side of this modified case, but the tide upended the mine and increased the submergence over that for the normal method of anchoring with the mooring rope at the end.

In case of emergency very useful mine cases can be improvised from good, strong kegs.

An effective submarine mine must have within it a piece of apparatus which will close the electric circuit as soon as a vessel strikes it. This piece of apparatus is called the circuit-closer, and there are many forms of it. In some cases there is a suspended cone with a good deal of inertia, to which the electric wire is connected. A spring attached to the case is placed so that when the case is struck by a passing vessel the cone will touch the spring. The conductor leading into the mine is grounded by this operation, and if the other pole of the battery is grounded also the electric circuit will be completed when a mine is struck and a current will pass through the fuses. The fuses used are of the ordinary type, consisting of a short piece of platinum wire surrounded by mercury fulminate. The wire is heated by the passage of a current and the detonator causes the explosion of the entire charge. To ensure explosion two fuses in multiple should be used.

If the mine be of the controllable type it may be arranged so that the current which passes through the circuit upon the striking of a mine by a vessel will cause an alarm in the operating room on shore but will not fire the fuse. This effect may be accomplished in many ways—these constitute the principal secrets of the mine systems in use.

The explosives which have been used in submarine mines are black powder, dynamite and wet guncotton; of these the last two are the only important ones. General Henry L. Abbot, of the United States Engineer Corps, performed some very valuable experiments in the early 70's with a view to determining the best explosive for use in submarine mines. In this connection he enunciated the following requirements:

1st. The greatest possible effect when fired under water in such envelopes as are suitable for submarine mines.

2d. Retention of normal strength under the conditions incident to the service, to wit: lapse of time, alternate freezing and thawing, occasional wetting and even saturation with water.

3d. Convenience in loading—involving safety in transportation and handling with ordinary roughness—a form which

admits of ready insertion in a hole small enough to be rendered watertight, and a high density in small bulk.

These three conditions are as true today as thirty years ago, but modern requirements compel a fourth—the explosive for submarine defense of our forts must be stored at the forts and ready for instant use.

There should be added also the following: A mine must not be dangerous if torn from its moorings. The peril in the Eastern Seas due to vagrant mines used in the Russo-Japanese war is well known to the navigators of those waters, and on many occasions innocent travelers have been exposed to drifting mines, and merchantmen have been destroyed more than a year after the termination of the war.

The picric-acid high explosives have received much attention for warlike purposes within the last decade, but they are not suitable for submarine mining. The explosive used by the United States in the Spanish war was dynamite of various grades. According to General Abbot's experiments this explosive (seventy-five per cent.) is stronger than wet guncotton in the proportion of seventeen to fifteen, and one hundred pounds of it has a destructive radius for battleships of about sixteen feet. In some recent experiments with another high explosive it was found that sixty-three pounds would produce serious injury at a distance of twenty feet, while one hundred and thirty pounds at a distance of fifteen feet disrupted entirely the double bottom of a target made to represent a section of a battleship. The utmost care must be used in loading submarine mines with dynamite, and it should be put into the mine case in ordinary packages containing about five pounds.

The priming charge to be placed around the fuses should be of loose dynamite, one pound in weight, carefully packed in a small bag (cotton or linen), the fuses inserted in holes made with a soft pine stick, and the whole tied around the choke with a piece of string. On account of the severe headaches which result from handling this explosive it is important that the operators should use rubber gloves. Special attention must be paid to the screw threads of the loading

hole. Before the closing plug is screwed in these threads should be scrubbed carefully with a soft brush.

Sixty per cent. dynamite is the strongest commercial product at present and should be used if this explosive is employed for submarine mining purposes.

The greatest danger to be apprehended in using dynamite is the leakage of the nitroglycerine. This is certain to occur if the least bit of water has access to the explosive. Very serious accidents have resulted from the explosion of a film of nitroglycerine on the inside of a mine case after the entire charge had been removed. If it is necessary to remove the closing plug from a mine case loaded with dynamite some mechanical arrangement should be rigged up so that the plug may be unscrewed from a distance.

Wet guncotton is an ideal explosive for mines and is used universally in modern torpedoes. The priming charge is dry guncotton, and to be certain of detonation arrangements must be made so that the primer will be separated from the charge by a non-metallic substance. In some experiments made at the School of Submarine Defense to determine the limiting distance at which dry guncotton will explode wet, it was discovered that wire mesh of copper between the dry and the wet would prevent detonation, whereas detonation would occur in every instance with a half an inch of non-electrical conducting material such as hard rubber or wood separating the primer and charge. It was found in the course of these experiments that the character of the material separating the primer and the charge was much more important than the dryness of the primer, and that wet guncotton with twenty-five per cent. of moisture could be fired with a primer which was itself far from dry. The strength of wet guncotton is to that of dynamite in about the proportion of fifteen to seventeen, and one hundred pounds of it can be relied upon to damage a ship at a distance of fourteen feet.

Some recent experiments have been made with a view to determining the character of a subaqueous explosion and the results have been very interesting. These experiments were

made with tri-nitro-toluol. $C_6H_4(NO_2)_3$. They demonstrated that there are two phases of a subaqueous explosion—percussive, in the nature of wave motion, and pressure; the former acts first and extends to a great distance, the latter exerts pressure due to a displacement of the material, but does not extend a very great distance from the mine. The former depends upon the rate of detonation and amount of gas; the latter upon the volume of gases, temperature of explosion and density of charging. The pressure effect comes after the percussive, and to the latter the destructive effects are largely attributable. The experiments showed that the percussive effect of tri-nitro-toluol is twenty-seven per cent. greater and pressure effect seven and one-half per cent. greater than those of wet guncotton, bulk for bulk. Furthermore, tri-nitro-toluol is very insensitive to shock, may be stored indefinitely with absolute safety, is not dangerous to handle, and may be used in loading with great facility. It is not affected by water, may be melted and cast into any shape; it may be fired by the detonation of a loose crystalline form of the same material. It will be seen from the foregoing that this explosive fulfils to a high degree the necessary requirements for submarine mining.

It has been noticed often by observers at some distance from an exploding mine that the fish jump from the water before any sound is heard or eruption noticed. The arrival of the percussive wave is very noticeable on a large vessel several hundred yards from the explosion. In one instance a condenser pipe was sheared off when a mine planter was about three hundred yards from the exploding mine, and the firemen often are very uncomfortable on mine planters, even though the vessel may be more than a thousand yards away when the mine is fired. In observing the water just above an exploding mine a mound will be seen to form and then a column shoot up to many feet, the height depending upon the submergence; a light target above the mine is projected upward ahead of the column.

The mine case may be fixed in position by a cast-iron

Fig. 1.—Two 32-Inch Mine Cases Supported on Stands.
The Loading Hole is Covered by the Cap to which the Mooring Rope is Attached.

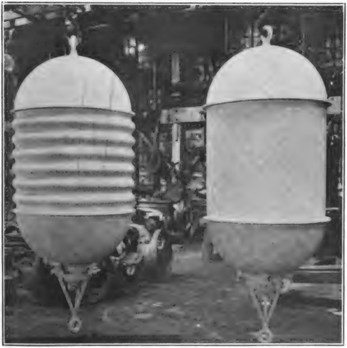


Fig. 2.—Mine Cases for Swift Currents.
The Corrugated Cylinder is the Latest Type and this Construction Has Diminished the Weight Very Materially.

Fig. 3.—A Typical Mine Explosion.
The Mine in This Case was Moored so that it was Very Near the Surface.

Fig. 4.—This Shows a Mine Ready For Planting.
The Cable Runs Aft where it is Coiled as a Figure Eight.

Fig. 6.—A Fleet of Mine Planters.

anchor cylindrical in shape and of a weight depending upon the buoyancy of the mine and the swiftness of the current. In this case it is necessary to take soundings and plant the mines very approximately at the places for which soundings were taken. This is very difficult in water more than one hundred feet deep, and has given rise to experiments to develop an anchor which will enable the mine to be moored at the proper depth below the surface without the necessity of taking soundings. All governments have an anchor of this nature, and most of them consist of a semi-ellipsoidal cast-iron case inclosing a drum upon which the mooring rope is wound. The drum is allowed to revolve during the descent of the anchor until it reaches a certain distance from the bottom when the revolution ceases and the mine is pulled down upon further descent of the anchor. These operations are brought about by having on the drum a ratchet into which a dog is pushed by means of a spring. If the tension of the spring is overcome the dog is pulled out of the ratchet and the drum revolves. A heavy lead weight is attached to this dog so as to overcome the tension of the spring and is of such a shape that its tendency to sink is greater than that of the anchor. The dog is thus pulled out of the ratchet and the drum revolves until this weight hits the bottom. As soon as the weight touches bottom the dog engages and stops the revolution of the drum. The weight is set at a distance from the anchor depending upon the depth at which it is desired to moor the mine case, the state of the tide and character of bottom. Effort has been made from time to time to produce an anchor which would accomplish the purpose noted above and also cause the anchoring rope to be lengthened and shortened as the tide rises and falls, thus producing a constant submergence for the mine case. This has not been accomplished successfully, and I think it is safe to predict that it will not be in the near future. Mines may be planted with facility in any depth of water up to two hundred feet.

The interval between mines may be fifty feet without danger of damage from a neighboring mine when the charge is

one hundred pounds of high explosive. This small interval is not necessary, as the beam of a battleship is more than seventy-five feet and the destructive radius of the explosive about fifteen feet. From these figures the maximum interval at which mines should be planted to close a channel with certainty is about one hundred feet. The mines are planted in groups of any desired number. From each mine a single-conductor cable runs back to a box called the distribution box. From the distribution box a multiple cable runs to the shore, and in the box electrical connection is made between the single conductor and a conductor of the multiple cable. The best system of mining is that where only one single-conductor cable is joined to each conductor of the multiple cable, for in this case each mine is independent of the others. However, if it is considered desirable, more than one mine may be joined to a single conductor of the multiple cable and in this way the mines operated from one multiple cable made to cover a much greater width of channel; independent action and control are sacrificed, but the expedient may be necessary in case of a shortage of multiple cable. From the distribution box the cable runs to the operating room of the fortification, and through a hut when this room is removed some distance from the shoreline. The hut should not be located immediately at the water's edge.

In order to permit friendly vessels to pass through a mine field without danger to the vessels or the mines, the different lines should not extend all the way across the channel, but should overlap, leaving a distance of five hundred or more yards through which a ship may pass when running on specially-located range points known only to certain pilots who would be used to take all vessels in and out of the harbor. In case of extremity these openings could be closed up quickly from the reserve supply of mines for the fort.

The operating room on shore contains all necessary electrical apparatus and appliances for automatic testing and firing of the mines or performing the same functions at the will of the operator. The methods employed for this pur-

pose are also secrets of the different mine systems. An efficient mine system requires that the testing should be simple and firing certain.

Mine planting is a very interesting operation, and the hazards involved with certain classes require the utmost precaution and alertness. Something new is developing always, and some loaded mines should be used constantly to prevent the apathy which comes from employing sand charges only in practice. To plant non-controllable mines one vessel is necessary; mechanical arrangements are made on board so that the mines with their anchors may be dropped at desired intervals as the planter runs a course; the proceeding is extremely dangerous. To plant electrically-controlled mines three vessels at least are necessary—a mine planter, a distribution-box boat and a small power launch as a marking boat. A tug one hundred and fifty feet in length and twenty-five to thirty feet beam will answer as a mine planter. Large deck space forward and little rigging to the rails are desirable. Fig. 4 shows a planter with a mine prepared for launching. Good steam or electrical winches are necessary.

The distribution-box boat should be short and broad of beam. A raft made by flooring over two sand scows may be used for this purpose in emergency. A powerful gasolene launch, about thirty feet long should be used as a marking boat.

The mines, anchors, mooring rope and other appliances are piled conveniently on the forward deck; the mine cables attached to the mines carried aft and coiled in the form of figures of eight piled on top of each other in the proper order. A group of mines is shown in Fig. 5.

The center mine is planted first and the others alternately from the port and starboard sides. A buoy is dropped to show where the first one is to go, the power boat ties to the first mine planted and acts as a marker for the next two; then it picks up the buoys of the mines successively so as to act as a marker throughout the entire operation. To plant a mine the mine planter passes near the distribution-box boat, throws

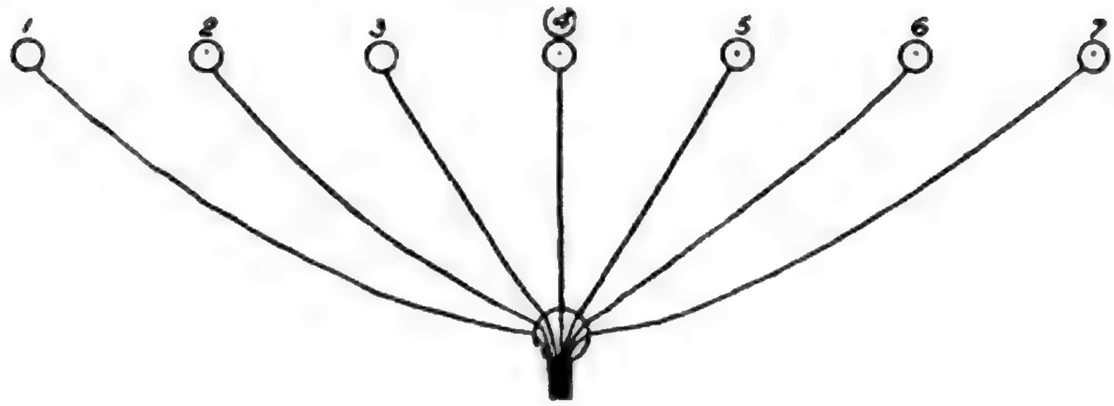


Fig. 5.

a cable to it, and proceeds to the point where the mine is to be planted. The cables pay out, and when the desired spot is reached the mine and anchor are both dropped at the command "let go;" best results are obtained by dropping the anchor a trifle sooner than the mine.

A channel may be closed in this manner at the rate of eighteen hundred feet in two hours and a half; therefore one planter with its small boats can close one and a third miles of channel per day. This is under the supposition that everything is ready for operation when the order is given.

The mine field is but one of the elements of harbor defense, and these are all so related and interdependent that it is necessary to consider each to a greater or less degree to appreciate the true part that any one of them plays.

In the evolution of coast-defense appliances the direct-fire gun was naturally the first to be developed, and all energies were spent toward that end. As time progressed certain other elements appeared, but until recently have been considered and classified as auxiliary. One of the fundamental laws of evolution is that it proceeds with rapid strides when conditions are ripe; this applies with wonderful exactness to the so-called auxiliary during the last decade. In fact, so rapid has been the progress that today the main elements of harbor defense are direct-fire guns, mines (including torpedoes), mortars and searchlights; the first being given precedence only by virtue of its age. If we consider their moral effect, their present state of efficiency and accuracy and the damage when success-

ful, the mine and mortar may be considered the most important factors in deterring an enemy from attacking a fortified harbor. However, it is considered that the functions of all these elements are so coördinate that each must be rated of prime importance, and incomplete without the coöperation of the others. To appreciate this we have but to consider the uselessness of guns—including mortars—at night without their eyes in the form of searchlights, and, in turn, of the uselessness of searchlights in smoke, fog and mists, in which case the defense would be practically helpless without mines; these, on the other hand, must be protected by guns during the period preceding the mist or fog under cover of which an attacking fleet would attempt to force a passage. Period preceding is used advisedly, for modern mine fields cannot be tampered with sufficiently during the fogs and mists to make a passage through which a fleet of battleships would attempt to pass. It should not be necessary to emphasize the absolute necessity of mines, to anyone who has observed the ease with which ships navigate the channels of our northern harbors through a mist so thick that range finders cannot be used.

The interdependence of guns and mines was recognized, though not acted upon, years ago. In the report of the Endicott Board the following principles were enunciated: "Without powerful guns in the defense the armored ships of the enemy would proceed deliberately to the removal of the mines; and without the aid of mines the enemy's vessels could not be prevented, generally, from running past the batteries."

This statement is true provided the defense is supplied with the means of meeting an attack of mine fields made by modern submarine boats, and it may be asserted confidently that, so long as the gun defenses are efficient, the mine fields cannot be disabled seriously, and so long as the mine fields remain in operation no naval commander will ever risk voluntarily a battleship, the mainstay of his country's naval strength, and an element whose loss would be irreparable within the duration of a modern war, in a hazardous attempt to pass such a field.

In a paper on ships and fortifictions a prominent naval authority says, in effect, that fleets will not attack alone harbors fortified properly, and that their use in such attacks will be simply supplementary to attacks from the land side. Fortified properly, in the statement, had special reference to mines and mortars.

Let us now consider the mine defense. The elements of this are fixed mines, previously described, and automobile torpedoes. Mines became practical and valuable, though very uncertain, factors of defense, in the Civil War. The limited success obtained with them, however, did not seem to produce much effect, as no nation since that time has shown in warfare that she has a submarine defense worthy the name, and some have shown hopeless grasp of the possibilities of torpedoes and mines. The wonderful efficiency of these weapons in destroying vessels has been well demonstrated in the recent war in the East. There mechanical mines were employed. These, owing to their cheapness and quickness of planting, appeal to some, but their uncertainty, their danger to friend as well as foe, and the lack of knowledge of their state and position after their planting, make their use prohibitive except in harbors of no importance and no commerce.

The splendid results of a comparatively inefficient mine service in the hands of the Confederates was a fine example of what may accrue to a weak adversary from the efficient use of a mine system. Furthermore, an effective gun and mine defense of a harbor is a source of great strength to a navy, for the prime objective of the latter is the enemy's fleet. A fleet is essentially an offensive weapon, and a country whose policy calls for detachments from its fleets to protect its ports can be condemned only in the strongest terms. Naval offense is the paramount consideration in any successful war, naval defense the most expensive and precarious undertaking, and has only one conclusion well exemplified in the last two wars. Anything which in the smallest way contributes to the former and relieves the latter may be considered a most valuable asset to any country. With our shore defenses per-

fected our navy may cut loose and carry war wherever strategic reasons may require.

The only safe and effective mine system is the electrically-controlled. With such a system the mine fields may be kept in repair, the operator has absolute information as to the condition of every mine and the mine may be made perfectly safe for friendly vessels; these characteristics are the prime considerations.

The cost of mine defense is a mere bagatelle when compared with that of any other. The entire material for all harbors of a country like ours will cost little more than half that of a single battleship, viz: about $4,000,000.

The personnel necessary for keeping the material in perfect condition, planting at a moment's notice and operating, is about five thousand officers and men. I have stated here, planting at a moment's notice under modern conditions; this is really the determining factor of an efficient mine defense.

The service of the mine fields includes not only planting, repairing and operating the mines, but also serving rapid-fire guns for mine field protection. The mine organization for a typical harbor contemplates a mine commander who will have command of all personnel connected with mine operation and the protection of the mine field. He will have a station in electrical communication with his rapid-fire guns, his searchlight and his operating room, so that he may exercise control readily over all of the units of his command. He would require as his assistants two officers for the service of the mine field, two for rapid-fire guns and two for operating the system. After the mines are down, enough men will be liberated from the planting detachment to form an effective nucleus for manning the rapid-fire guns to protect the field. A careful consideration of all the difficulties to be encountered by small boats in attempting an attack on a mine field will show that the number of rapid-fire guns for its protection will bear only a small ratio to those that will be necessary for action against small craft which may attempt to force a passage into a harbor.

Mines may be planted with facility in water whose depth is two hundred feet, and may be planted in deeper water, but the difficulties increase very rapidly with the depth. Damages to a mine field from attack or other cause may be repaired readily by planting in rear of the opening due to the disabled mines.

It is at present impracticable to defend by submarine mines certain of our harbors and waterways (few, it is true, yet of the utmost importance) owing to excessive width or great depth of the channel, or to unusual swiftness of the current (these factors existing singly or in various combinations). In such situations the automobile torpedo is a necessary adjunct to the mine field. There are certain limitations to the use of this weapon.

1st. Its range is restricted; therefore it is unsuited to a channel over two and one-half miles in width.

2d. It is launched from a tube either beneath the surface of the water or at a height not greater than nine feet above the surface, and for success the water beneath the point of launching should be at least thirty-six feet deep. This last requirement restricts the use of such torpedoes to those situations where the water near the shore is of unusual depth, or else involves a construction of costly and bulky launching platforms, ordinarily requiring expensive artificial protection. Therefore, these torpedoes cannot be employed, in general, where the channel is very wide or where the shores are low and where there is an extent of shallow water between the shore line and the requisite deep water. Furthermore, their accuracy decreases rapidly with increased range and their range is quite limited, hence for wide channels the advisability of using them from shore stations is much to be doubted.

Full consideration of the various difficulties involved in operating effectively the launching of automobile torpedoes led the Board of Engineers, in August, 1902, to suggest the use of scows for firing platforms, rejecting all ideas of shore stations proper.

Reflection will show that in order to protect such scows

they must be converted into armored vessels, and that with the exception of slight mobility nothing would be gained. Therefore we conclude that the proper launching platforms for the automobile-torpedo defense of a harbor are the torpedo boat and submarine boat; the latter is the ideal coast-defense launching platform for this purpose. It possesses in a high degree the valuable properties of mobility, concealment and efficiency, and in addition it may, within limits, select the most advantageous time and point of attack.

Besides this particular use the submarine boat will prove undoubtedly of great value in harbor defense for the following purposes:

1st. As a means of keeping a blockading fleet at a great distance from the harbor entrance at night and also preventing hostile ships from anchoring at any time in the vicinity of the entrance.

2d. As outposts and scouts to prevent interference with the mine field by surface boats in foggy weather or by submarine boats at any time.

For attaining these objects only the smaller or harbor type of submarine is necessary. The uses outlined here for submarine boats as adjuncts to fixed coast defenses are purely defensive or defensive-offensive, and are distinct from the essentially offensive use to which such boats will be put by an enterprising navy.

The zone of activity of the fixed defenses of a harbor is that covered by their heavy-gun fire, and within this zone there can be no division of authority; that is, the commander upon whom the responsibility of the defense devolves must have unquestioned and absolute control of all the defensive elements. Therefore it follows that where such boats are provided they should be made an integral part of the artillery district command, not separated therefrom except in great emergency, and then only by the highest authority.

The present type of submarine is purely a harbor-defense boat and may be called a local issue.

It is not contended here that the army should furnish the

officers and supply of these boats, but that they are part and parcel of the proper defense of an artillery district, and should be under the district commander for tactical use. They are on the border line between the coast artillery and naval services. The navy graduates into them in its offensive-defensive rôle, the coast artillery does likewise in its defensive-offensive operations.

Having outlined the main elements of the defense and given somewhat in detail the factors of the submarine part, we will consider their relation in battle. The battle area for heavy guns extends to 12,000 yards. If mortars are located on the main line of defense they can cover any of the area from the outer limits to a point two thousand yards from the main line. In the outer limits little is to be feared from the ship, but, all things considered, the shore guns have some chance of disabling the enemy; within the destructive area from four to eight thousand yards, the rapid-fire guns of the fleet will not be effective, but the heavy guns of the defense will be destructive if concentrated on the enemy; the rapid-fire guns of the defense will be effective likewise against small vessels in the nearer portion of this area. Within four thousand yards the rapid-fire guns of the enemy will be effective, as well as the high-power guns.

The mine field must be located tactically with the foregoing in view; the other factors involved in the problem, being local, to wit: width of channel, depth of harbor, swiftness of current.

We find nearly all writers asserting that mine fields may be put out of action—

1st. By grappling for cables and junction boxes.

2d. By countermining.

3d. By sweeping.

I wonder how many authorities who have made these statements ever tried any of these operations. I will venture to say none. I have tried some of them under the most favorable circumstances, viz: in broad daylight with a calm sea; even under these conditions very little was accomplished in a

long time. I have also tried them at night when I knew just where the mines were, and it was a hopeless task. Such has been my experience that I am willing to assert positively that nothing is to be feared in fair weather from an enemy who tries to disable a mine field by any of these methods, so long as there is any shore defense at all. In case of moderately thick weather something might be accomplished, but I am convinced that the mine field *in toto* cannot be put out of action so long as the shore defense offers any resistance.—"Journal of the U. S. Artillery."

SPEED TRIALS AND SERVICE PERFORMANCE OF THE CUNARD TURBINE STEAMER *LUSITANIA*.*

By Thomas Bell.

The following hourly abstract on one of the watches on the *Lusitania* brings home to one's mind the loss in steam and speed caused by cleaning fires, especially when the coal is small. It can be easily calculated from this what an appreciable increase in the ship's mean speed could be obtained from this cause alone, if the price and supply would admit of the use of some system of oil-fuel burning:

......	Mean Revolutions.	Corresponding speed of ship.	
First hour	178	about 24.0 knots	24.15
Second hour	181	about 24.3 knots	
Third hour	186	about 25.0 knots	25.05
Fourth hour	187	about 25.1 knots	
Mean for watch	183	about 24.6 knots.	

Regarding the observations from readings taken in the engine room on the official trials generally, it may be stated that on the measured miles the revolutions were obtained from electric records in connection with the pallograph apparatus, but on the lengthened trials they were taken from half-hourly readings of the engine-room counters. The vacuum recorded is that of the vapor in the main exhaust orifice forming the top of the condensers, and as measured by a siphon mercury gauge, the readings of which throughout are corrected to correspond to a 30-inch barometer. The total quantity of feed water is obtained from hourly counter read-

* Read before Institution of Naval Architects, April 9, 1908.

ings of the double strokes of the Weir's feed pumps, the average length of stroke and the slip or leakage of each pump being determined, both before and after the trials, by careful tests.

The consumption of steam of the auxiliary machinery is obtained by noting the amount by which the temperature of the total feed water was raised in the feed heaters, and to the amount thus found must be added the steam used in the turbo-generators, the exhaust from which was led direct to the auxiliary condensers on the official trials. As before stated, in actual service these turbo-generators exhaust into the contact heaters, and thus raise the feed temperature to about 200 degrees. These connections had to be slightly altered at the time of the trials and, unfortunately, therefore, advantage could not then be taken of this additional source of economy.

The torque horsepower was obtained by the Denny-Johnson apparatus, and the records show that, while a propulsive efficiency of the whole installation was obtained which accorded with the original estimate, the steam consumption of the turbines themselves was very satisfactory. It need hardly be pointed out that those two, viz: propulsive efficiency and steam consumption per unit of power, form an excellent check on each other, for whatever would unduly favor one would be at the expense of the other.

Table I.

Time.—Double runs.	Pressures.		Vacuum at 30-in. barometer.	Revs. per minute.	Speed, in knots.	Shaft horsepower.	Slip of propellers, per cent.
	H.P. receiver, pounds.	L.P. receiver, pounds.					
First	157	5¼ pounds	28.0″	194.3	25.62	76,000	17.2
Second	135	2½ pounds	27.9″	186.0	25.0	65,500	15.5
Third	110	½ pound	28.1″	174.2	23.7	51,300	14.5
Fourth	90	3¼″ vac.	28.1″	161.5	22.02	40,500	14.3
Fifth	70	6¼″ vac.	28.0″	147.6	20.4	29,500	13.1
Sixth	50	10¼″ vac.	28.0″	131.1	18.0	20,500	13.7
Seventh	35	14½″ vac.	28.1″	116.1	15.77	13,400	14.6

The *Lusitania* was floated out of dry dock at Liverpool on July 22, 1907, and was thereafter coaled by the Cunard Company, the bunkers for the forward and after boiler rooms being filled with South Wales coal, and those of the two middle boiler rooms with Yorkshire coal.

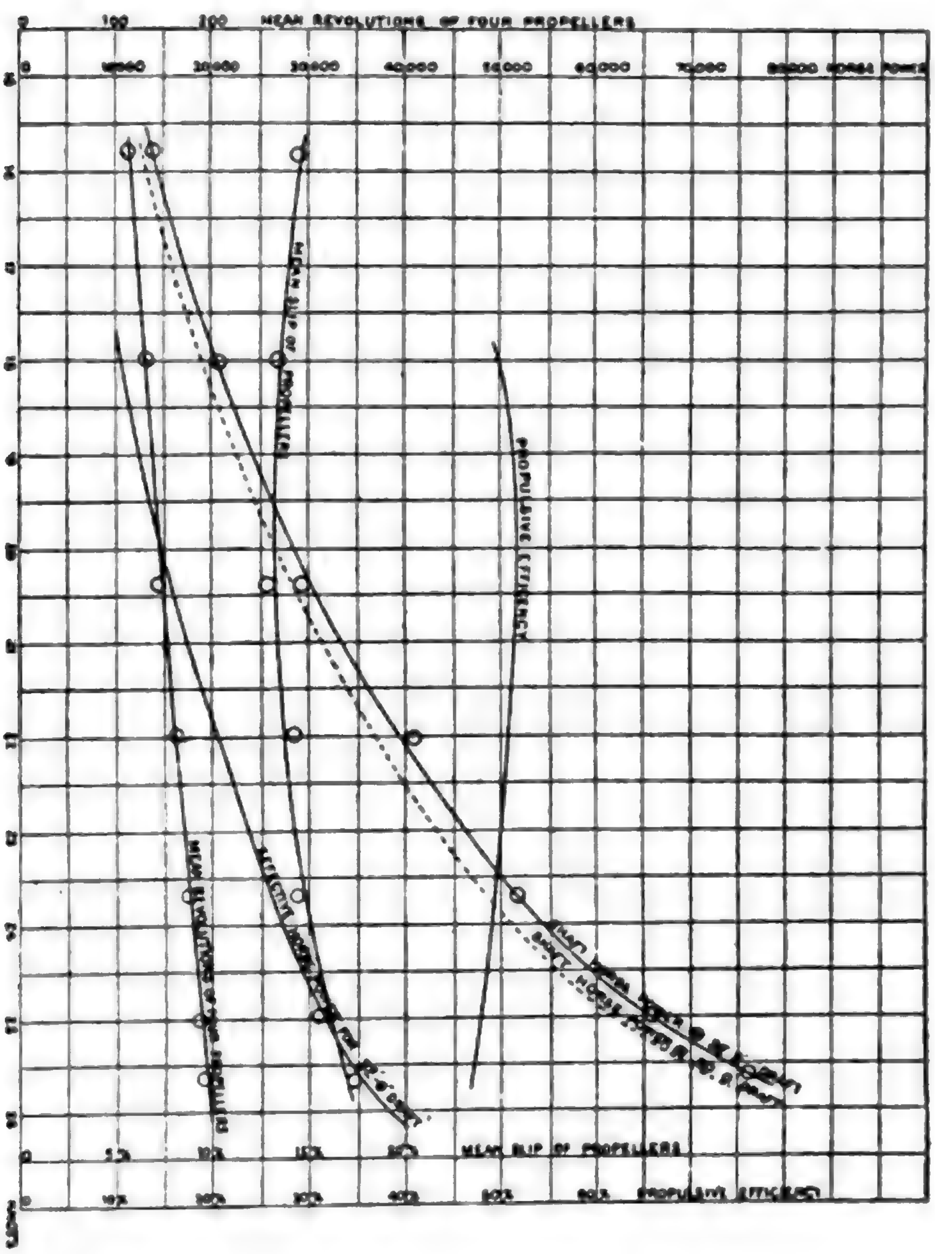


Fig. 5.—PROGRESSIVE TRIAL, JULY 27, 1907, OFF SKELMORLIE.

On her return to the Clyde, on the morning of July 27, a series of progressive runs was made on the Skelmorlie measured mile, as recorded on Table I, with the ship at a mean draught of 32 feet 9 inches, corresponding with a displacement of 37,080 tons. These results are also given in graphical form in the diagram on Fig. 5, which gives curves of

shaft horsepower, revolutions and slip on a common speed base. Two other most interesting curves have been added, one showing the effective horsepower determined by means of tank experiments, and the other showing the propulsive efficiency. It was intended to repeat this trial at the termination of the official trials, at a mean draught of about 30 feet. Unfortunately, however, thick weather on the morning of August 2 prevented this being carried out, but the dotted curve on Fig. 5 indicates with sufficient accuracy what might have been expected.

On the evening of the 27th the *Lusitania* proceeded on a pleasure cruise around Ireland, during which consumption trials at 18, 21 and 23 knots were carried out, and, after landing the guests in the forenoon of the 29th, the vessel returned to the Clyde, making a consumption trial at 15¾ knots *en route*, the results of these trials being given in the first four columns of Table V. After checking the draught of ship, etc., the 48-hours' full-speed continuous trial was commenced at midnight. This trial consisted of two double runs on a course of 304 nautical miles between Corsewall Point and the Longships, and the results obtained are recorded on Table II and the last column of Table V. The mean draught at starting was 32 feet 7 inches, and at the finish about 30 feet 8 inches, the mean for the run having been 31 feet 7½ inches, corresponding with a displacement of 35,600 tons.

Table II.

Time.	Pressures. H.P. receiver, pounds.	Pressures. L.P. receiver, pounds.	Vacuum at 30-in. barometer.	Revs. per minute.	Speed, in knots.	Shaft horsepower.	Slip of propellers, per cent.
First run	146	2½	27.9″	188.8	26.35	70,400	...
Second run	145	2½	28.0″	187.4	24.3	68,200	...
Third run	146	2¼	27.9″	187.5	26.3	68,700	...
Fourth run	148	2¼	27.8″	187.9	24.6	68,100	...
Mean of means	146	2½	27.9″	187.9	25.4	68,850	15

The coal consumed in the fifty hours during which the engines were running at full speed was found by measurement of bunkers to be about 2,200 tons. This represents an evaporation of 10.1 pounds of water per pound of coal from 165 degrees temperature of feed, or 11.1 pounds from and at 212 degrees, and a consumption of coal for all purposes of 1.43 pounds per shaft horsepower per hour, with a rate of combustion of coal of 24.3 pounds per square foot of grate surface per hour. The number of stokers on watch was the same as in actual Atlantic service, and the air pressure in the ashpits did not exceed ¾ inch of water column. The port evaporators were used for ten hours of the trial; but, as the vapor from these was condensed in the port auxiliary condenser, to which the exhaust from one set of the turbo-generators was led, they were discontinued and the make-up feed obtained from the reserve tanks for the remainder of the time.

The third trial, recorded on Table III, which was commenced in the forenoon of August 1, consisted of one full-power double run between Corsewall Point and the Chicken Rock, a distance of 59 nautical miles each way, but comparison with the dotted curve on Fig. 5 shows that the tide conditions during this trial give altogether too favorable a speed

Table III.

Time.	Pressures.		Vacuum at 30-in. barometer.	Revolutions per minute.	Speed, in knots.	Shaft horsepower.	Slip of propellers, per cent.
	H.P. receiver, pounds.	L.P. receiver, pounds.					
First run	152	2¼	28″	191.3	26.75	72,000	......
Second run	152	2¼	28″	191.7	26.17	72,800	......
Mean	152	2¼	28″	191.5	26.46	72,400	13.2

result. The mean draught was 30 feet 4½ inches, corresponding with a displacement of 34,160 tons. The vessel was then headed for Ailsa Craig, and carried out the specified six full-power runs between Ailsa Craig and the Holy Isle (off Arran).

These latter, recorded on Table IV, which were run at a mean draught of about 30 feet 2 inches, corresponding with a displacement of 33,770 tons, give a very reliable record of power and speed at this draught, when compared with the 25.62 knots obtained on the measured mile at 32-feet 9-inch draught. On the following day weather conditions precluded any further trials, and the reversing trial and the steering and circle-turning trials were accordingly carried out on the vessel's passage to Liverpool on August 26.

In a fast passenger liner, such as the *Lusitania*, it is of the utmost importance that the maneuvering capabilities should leave nothing to be desired, and to demonstrate the possibilities of the ship in this respect, various trials were made, the most important being the following:

Stopping trial.—The ship was run on the Skelmorlie measured mile at a speed of 22.8 knots, the average revolutions of the propellers being 166 per minute. On entering the mile, the engine-room telegraphs were rung to "full speed astern;" the ship was brought to rest in 3 minutes 55 seconds, the distance run being about three-quarters of a mile, or about six times the length of the ship. During this trial the boilers in the three after boiler rooms only were in use, and the initial pressure at the astern turbine was about 90 pounds per square inch.

Table IV.

Time.	Pressures.		Vacuum at 30-in. in barometer.	Revolutions per minute.	Speed, in knots.	Shaft, horsepower.	Slip of propellers, per cent.
	H. P. receiver, pounds.	L. P. receiver, pounds.					
First run	151	$2\frac{3}{4}$	28″	191.3	25.62	72,500	...
Second run	152	$2\frac{3}{4}$	28″	191.1	26.36	72,000	...
Third run	153	3	28″	191.9	25.31	72,000	...
Fourth run	147	$2\frac{1}{2}$	28″	191.0	26.16	72,100	...
Fifth run	149	$2\frac{1}{2}$	28″	190.2	25.26	70,800	...
Sixth run	149	$2\frac{1}{2}$	28″	191.2	25.95	71,800	...
Mean of means	150	$2\frac{3}{4}$	28″	191.2	25.77	71,910	15.3

Circle trials.—With the ship initially on a straight course, and the turbines running at an average speed of 180 revolutions per minute, the steering wheel was put hard over in 17 seconds. The tiller went over to 35 degrees in 20 seconds, and the vessel made a complete circle in 5 minutes 50 seconds, the average revolutions coming down at the completion of the circle to 70 per cent. of the rate at the commencement. The resulting circular path was approximately 1,000 yards, or four lengths of the ship, in diameter. This maneuver was made both under starboard and port helm with very closely confirmatory results.

Going astern with the inner propellers running at a uniform rate of 136 revolutions per minute and under full helm, resulted in half circles being made in an average time of 6 minutes 45 seconds.

Table V.

ACTUAL STEAM AND COAL CONSUMPTION OF MAIN AND AUXILIARY ENGINES AT VARIOUS SPEEDS UNDER CONDITIONS PREVAILING ON OFFICIAL TRIALS, VIZ: TURBO-GENERATORS EXHAUSTING TO AUXILIARY CONDENSERS, OTHER AUXILIARIES EXHAUSTING TO HEATERS.

Shaft horsepower	13,400	20,500	33,000	48,000	68,850
Speed, in knots	15.77	18.0	21.0	23.0	25.4
Temperature of feed water	200°	200°	199°	179°	165°
Total consumption of auxiliaries, in pounds per hour	71,000	76,400	85,700	96,700	116,500
Total consumption of turbines, in pounds per hour	284,500	353,600	493,300	668,300	879,500
Steam consumption of auxiliaries, in pounds per turbine horsepower hour	5.3	3.72	2.6	2.01	1.69
Steam consumption of turbines, in pounds per horsepower hour	21.23	17.24	14.91	13.92	12.77
Total steam consumption, in pounds per horsepower hour	26.53	20.96	17.51	15.93	14.46
Coal consumption, in pounds per horsepower hour	2.52	2.01	1.68	1.56	1.43
Estimated coal consumption, in tons, on a voyage of 3,100 nautical miles, allowing 20 tons for galleys, etc	2,980	3,190	3,670	4,520	5,390

As important factors contributing to these very satisfactory results, it may be remarked that, following on the suggestion of Sir Philip Watts, the deadwood aft is cut away in a fashion

similar to that in recent warships. The inner propellers are fairly close together and, as the rudder is of large dimensions in the fore-and-aft direction, the race from these propellers impinges fully upon it when any helm is used. The vessel, consequently, is very similarly circumstanced to a single-screw ship, or a triple-screw ship with all three propellers in action, and gets steerage way without any perceptible head-way, and this feature was very noticeable during the steering trials. At first sight it would appear that the outer propellers should have been those utilized for maneuvering purposes, as the outer shafts have about three times the spread from the middle line that the inner shafts possess. For turning with propellers alone without the help of the rudder they would have been much the more effective, but they would not have possessed any such advantage as that alluded to above in respect to obtaining steerage way without headway.

Table VI.

ESTIMATED STEAM AND COAL CONSPUMPTION AT VARIOUS SPEEDS, ALLOWING FOR THE ADDITIONAL AUXILIARY STEAM CONSUMPTION FOUND REQUISITE UNDER ACTUAL SERVICE CONDITIONS FOR THE WASHING-WATER SUPPLY, ETC., WITH A FULL COMPLEMENT OF PASSENGERS, WEATHER CONDITIONS BEING AS ON OFFICIAL TRIAL.

Shaft horsepower	13,400	20,500	33,000	48,000	68,850
Speed, in knots	15.77	18.0	21.0	23.0	25.4
Temperature of feed water	200°	200°	200°	200°	200°
Total consumption of auxiliaries, in pounds per hour	93,500	100,900	112,700	127,500	149,700
Total consumption of turbines, in pounds per hour	284,500	353,600	493,300	668,300	879,500
Steam consumption of auxiliaries, in pounds per turbine horsepower hour	6.97	4.92	3.41	2.65	2.17
Steam consumption of turbines, in pounds per horsepower hour	21.23	17.24	14.91	13.92	12.77
Total steam consumption, in pounds per horsepower hour	28.2	22.16	18.32	16.57	14.94
Coal consumption, in pounds per horsepower hour	2.76	2.17	1.8	1.62	1.46
Estimated coal consumption, in tons, on a voyage of 3,100 nautical miles, allowing 20 tons for galleys, etc.	3,270	3,440	3,930	4,700	5,490

Table VI has been compiled for comparison with Table V, to show the additional consumption of steam for auxiliary purposes under actual working conditions at sea with the ship full of passengers. This shows very clearly the demand which modern improvements make on the steam, and hence coal consumption of a large passenger vessel. An additional line has been added to Tables V and VI to show total coal consumption on a voyage of 3,100 nautical miles at the various speeds and under the different conditions.

Table VII.

ABSTRACT OF ENGINE-ROOM LOG FOR THIRD VOYAGE WEST: QUEENSTOWN TO NEW YORK.

Date when last dry docked, July 22, 1907. Mean draught, leaving Queenstown, 33 feet 7 inches. Mean draught arriving New York, 30 feet 10 inches.

Date, 1907.	Steam Pressures. Boilers, pounds.	H.P. recrs., pounds.	L.P. recrs., pounds.	Temperatures. Hotwell.	Feed water.	Vacuum, inches.	Barometer, inches.	Length of day. H.	M.	Distance by observation, nautical miles.	Mean speed.	Mean revolutions.	Mean slip.	Coal consumed for main and auxiliary engines.
Noon,													P. ct.	Tons
Nov. 3	170.0	140.0	2.3	68°	200°	28.0	30.4	...	52	21	24.24	182.5	16.9	4[illegible]
Nov. 4	165.1	142.2	2.2	78°	197°	28.0	29.7	24	57	606	24.28	182.6	16.4	1,09[illegible]
Nov. 5	167.3	140.6	2.3	78°	198°	28.2	30.0	25	2	616	24.6	182.8	15.4	1,09[illegible]
Nov. 6	168.3	140.4	2.5	70°	196°	28.2	30.1	24	55	618	24.8	183.5	15.1	1,09[illegible]
Nov. 7	168.3	138.3	2.2	72°	195°	28.0	29.6	24	52	610	24.52	181.4	15.0	1,09[illegible]
1.14 a. m.,														
Nov. 8	165.0	132.5	1.5	75°	200°	27.8	29.3	14	2	310	22.09	174.0	22.2	*576
Means	168.0	139.3	2.2	74.5°	197°	28.1	29.8	...	...	...	24.25	181.1	15.9	4,976
Total	...	...	...	...	...	...	...	114	40	2,781	...	...	...	...

* This includes all coal used till 10 a. m. on the 8th.

Summary of total coal consumed on voyage: Liverpool to Queenstown, 408 tons; Queenstown to New York, 4,976 tons; galleys, etc., 18 tons; total coal taken from bunkers, from leaving landing stage, Liverpool, till moored at wharf, New York, 5,402 tons. Passage—Queenstown to Sandy Hook—4 days, 18 hours, 40 minutes.

With reference to the third voyage west, from November 2 to November 8 of last year, thanks to the courteous permission of the chairman of the Cunard Company, the leading particulars of the official engine-room log are summarized in Table VII. Regarding the mean draught of the vessel at sea, it may be remarked that, after the second day out certain of the forward tanks were gradually filled for the purpose of avoiding excessive trim, so that the mean draught on Novem-

ber 5, 6 and 7 was approximately 32 feet, or very little more than the mean of the first pair of runs from Corsewall Point to the Longships and back. The conditions, however, were otherwise very different, for, with the exception of the twelve hours of fine weather and smooth sea from noon till shortly after midnight on November 6, it was throughout the average mid-Atlantic winter weather—namely, strong winds and resulting boisterous sea. Up till midnight on the 6th, *i. e.*, for 2,176 out of a total of 2,781 nautical miles, the mean speed works out at 24.65 knots; but, unfortunately, early on the 7th the wind freshened, gradually increasing to a furious southwest gale, which reached its height about 4 P. M., and reduced the average speed for the last 24 hours below 23 knots, and thus brought down the mean average for the com-

Table VIII.

Date—1907.	Length of steaming day.		Distance run. nautical miles.	Speed, knots.	Total distance steamed.	Total time.		Mean average speed.
	Hrs.	*Min.*				*Hrs.*	*Min.*	
Noon, November 3......	0	52	21	24.24	21	0	52	24.24
Noon, November 4......	24	57	606	24.28	627	25	49	24.27
Noon, November 5......	25	2	616	24.6	1,243	50	51	24.44
Noon, November 6......	24	55	618	24.8	1,861	75	46	24.57
Noon till midnight, November 6............	12	30	315	25.2	2,176	88	16	24.65
Noon, November 7......	12	22	295	23.85	2,471	100	38	24.55
Morning, November 8.	14	2	310	22.09	2,781	114	40	24.25

pleted voyage to 24.25 knots. Table VIII, giving the mean average speeds at the different stages of the voyage, shows very clearly the effect of this gale, unfortunate so far as preventing the vessel from complying with the contract conditions, but giving those connected with the ship an opportunity of thoroughly satisfying themselves as to her behavior when driving through the huge waves at about 22½ knots, without any racing of engine or sign of laboring, and dis-

pelling the idea, current in some minds, that turbine-propelled ships do not show to advantage in heavy weather.

The following particulars of the steam consumption are given in conjunction with the figures of coal consumption set forth in Table VII. Throughout the voyage a careful record of the feed-pump counters gave an average of 998,000 pounds of water pumped into the boilers per hour. Of this, about 114,000 pounds was used by auxiliary machinery exhausting into the feed heaters, 26,000 pounds by the evaporating plant supplying feed make-up and washing water, and about 6,500 pounds for steam to the thermotanks, galleys and pantries, both of which latter figures are based on data obtained from tests carried out before the vessel left the Clyde. Hence, taking the average shaft horsepower as 65,000, the steam consumption per shaft horsepower per hour works out as follows:

	Total water.		Per shaft H.P. hour.
Main turbines	851,500 pounds	=	13.1 pounds.
Auxiliary machinery	114,000 pounds	=	1.75 pounds.
Evaporating plant and heating	32,500 pounds	=	.5 pound.
	998,000 pounds		15.35 pounds.

Average amount of coal burned per hour for all purposes = 43½ tons.
Water evaporated per pound of coal = 10.2 from a feed temperature of 196°.
Water evaporated per pound of coal = 10.9 from and at 212°.
Coal for all purposes per shaft horsepower, per hour = 1.5 pounds.
Coal per square foot of grate, per hour = 24.1 pounds.

Taking a mean displacement of 36,000 tons, this represents at 24½ knots a consumption of almost exactly 11 pounds of coal per 100 nautical miles per ton of displacement. The coal used was half South Wales and half Yorkshire, practically the same as on the official trials.—"International Marine Engineering."

A METHOD OF PROTECTING FROM CORROSION THE ENCASED PORTION OF PROPELLER AND STERN-TUBE SHAFTS.

By Leo Morgan, Member.

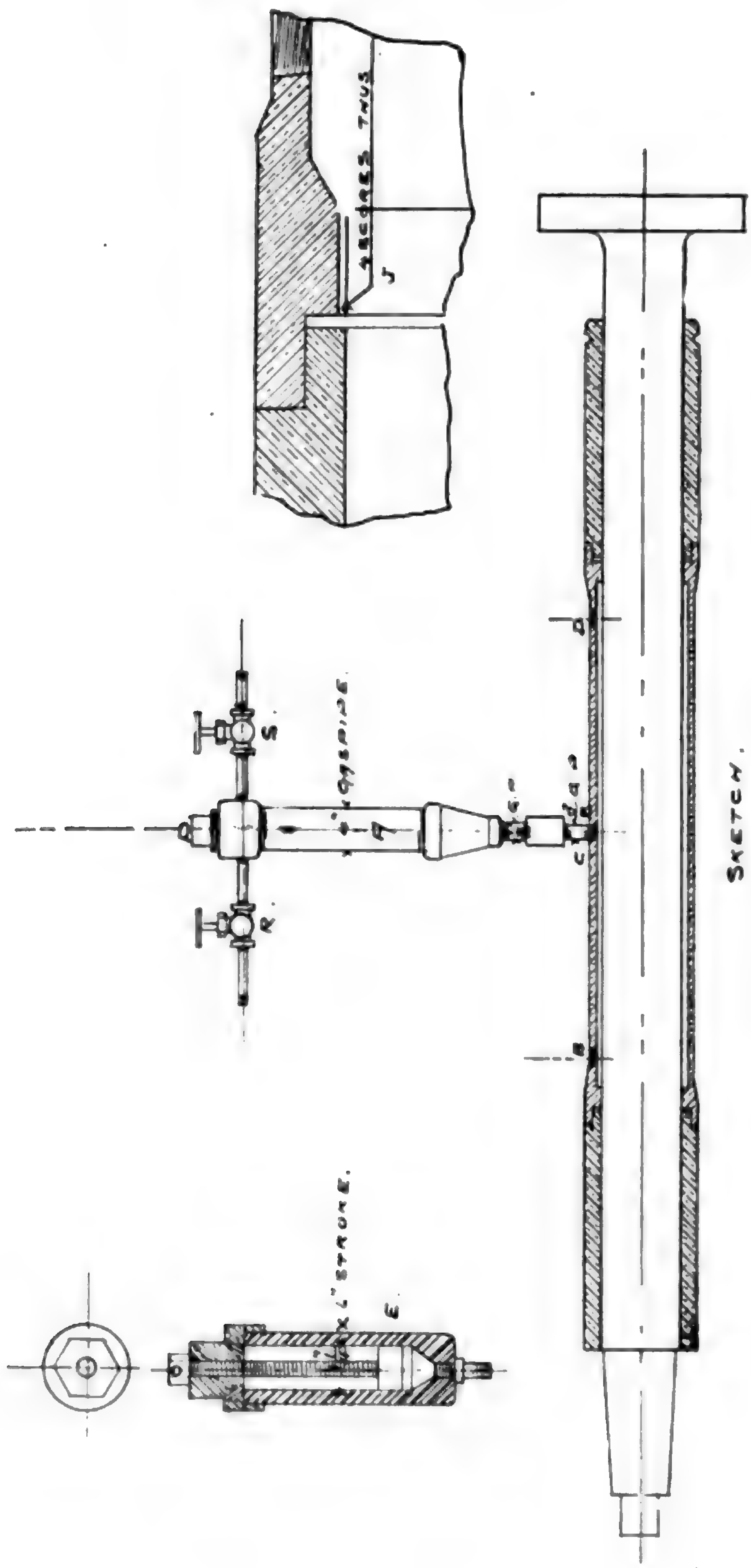
The method now in use at the Union Iron Works, San Francisco, Cal., for making propeller and stern-tube shaft casing watertight consists in forcing red-lead putty into the recesses between the shaft and casing.

The accompanying sketch will help to illustrate this process.

Each recessed section is drilled and tapped at about the center and near the ends B, C, D, for a $\frac{3}{8}$-inch gas-tap plug. The end bearings of these sections are also scored at four or more points (J) to allow the putty to flow into the joints. It will also be noticed that the joints stand apart on the inside and are closed on the outside.

The filling material consists of a thin and thick red-lead putty mixed with boiled linseed oil, forced into place by means of compressed air and a hand-pressure putty pump.

The charging chamber A, which consists of a piece of 4-inch gas pipe about 2 feet long, is fitted with a coned cap at at the lower end and at the top with a plug and two $\frac{1}{4}$-inch globe valves, R and S, for the supply and regulation of the air pressure. This chamber is attached at the center opening C, and filled almost to the level of the valves with the thin putty, the plug P inserted, and an air pressure of 50 pounds per square inch applied directly to the surface of the putty. When the recessed spaces are filled with the thin material the charging chamber is removed and the end holes B and D temporarily plugged. The putty pump E, operated


GROOVES THUS
SKETCH.

by a wrench, is now inserted at C, and the thick putty is forced into the casing until the space in its vicinity is filled solid. The pump is then removed and the hole plugged. This operation is repeated successively at the end holes, B, D, until the entire casing is filled solid, which is easily determined by lightly tapping the casing with a hammer.

In the event of the casing being porous, the putty is forced into the pores and sometimes through to the surface, thereby producing a lighter casing than can be obtained by either the tinning or the shellac treatment, and when properly done will, I think, give satisfactory results.

U. S. SCOUT CRUISER *BIRMINGHAM.*

DESCRIPTION OF MACHINERY AND OFFICIAL TRIALS.

BY COMMANDER THEO. C. FENTON, U. S. N., RETIRED.

The Scout Cruiser *Birmingham* was built by the Fore River Shipbuilding Company, of Quincy, Mass. The contract for this vessel was signed May 17, 1905, the price being $1,556,000. This price does not include the ordnance and ordnance outfit and certain articles supplied by the Government. The contract time for completion was thirty months. Owing to various delays for which the contractors were not responsible, this time was extended to February 11, 1908. The main engines were required to develop 16,000 indicated horsepower when making 200 revolutions per minute, with a steam pressure at the high-pressure cylinder of 250 pounds.

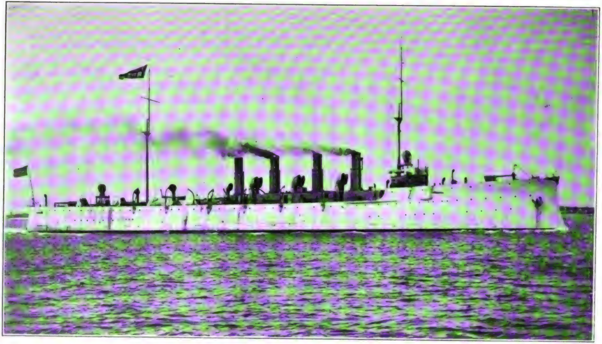
The guaranteed speed of the ship was twenty-four knots per hour for four hours in the open sea.

PRINCIPAL DIMENSIONS OF HULL.

Length between perpendiculars, feet	420
over all, feet and inches	423-02
on L.W.L., feet	420
Breadth, molded, feet and inches	46-08
Draught, fully loaded, feet and inches, about	19-01½
Displacement, loaded, tons, about	4,640
Draught on trial, feet and inches	16-09¼
Corresponding displacement on trial, tons	3,750
Displacement per inch at L.W.L., tons	31.13
Capacity of coal bunkers (43.5 cubic feet per ton), tons	1,379
engine-room feed tanks, tons	10.65
reserve feed-water compartments, tons	116.46

ELECTRIC PLANT.

There are three generating sets installed in this vessel. They are of 32-kw. capacity, having a full-load output of 256 ampères at 125 volts at a speed of 400 r.p.m., and were



U. S. SCOUT CRUISER "BIRMINGHAM."

manufactured by the General Electric Company, of Schenectady, New York. The generating engines are of the vertical, cross-compound, double-acting, enclosed type, with cranks 180 degrees apart, and are for a normal speed of 400 r.p.m., with a normal steam pressure of 100 pounds, and exhausting into the condenser.

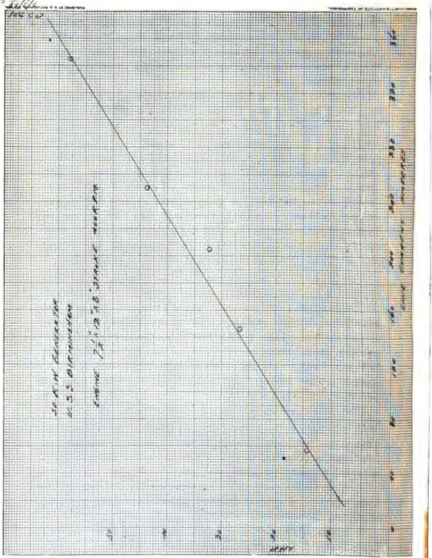
There is a heavy bedplate bolted to the foundation supporting the generating sets, that part of which is under the engine being enclosed and forming the reservoir for the oil used in lubricating the moving parts of the engine. This space is also utilized as a settling and cooling chamber, this chamber being in communication with a sight-tube oil gauge indicating the height of the oil therein. The upper part of the bed-plate casting contains a depression around the engine casing for the collection of waste oil and drippings, and is provided with suitable means of drainage. The moving parts of the engine are accessible through doors on the port side of the casing and the portable plate on the opposite side.

The range of steam pressure for these engines is between 80 and 120 pounds with a normal pressure of 100 pounds. At 80 pounds steam pressure and atmospheric exhaust the generating sets are designed to carry 90 per cent. full load; at 100 pounds steam pressure and atmospheric exhaust, or 80 pounds steam pressure and vacuum exhaust, they will carry full load, and at normal steam pressure and vacuum, or 120 pounds steam pressure and atmospheric, they will carry an over-load of 33 per cent.

The cylinders are 7½ inches and 12 inches in diameter with a stroke of 8 inches. Both cylinders, with their steam chests, are contained in a single casting of hard close-grained cast iron, accurately bored and covered with a thick layer of asbestos lagged with sheet iron.

The generators are of the direct-current, constant-potential, multi-polar type, compound wound with a series shunt, designed for no change in voltage at different loads.

Ventilating fans, deck winches, ammunition hoists and the fresh-water pumps are all driven by electric motors.


50 K.W. GENERATOR
U.S.S. BIRMINGHAM
ENGINE 7½" × 12" × 8" STROKE 400 R.P.M.
50
40
30
20
10
I.H.P.
0
40
80
120
160
200
240
280
320
360
LINE CURRENT AMPERES

ANCHOR WINDLASS.

The anchor windlass is of the Hyde type, manufactured by the Hyde Windlass Company, of Bath, Maine.

The windlass proper is of the vertical type and has two vertical shafts driven by worm gearing direct from a worm located on the crank shaft of the engine, without the intervention of counter shafts or bevel gears. Each shaft carries on its upper end above deck a wildcat with locking gear complete. The arrangement is such that the wildcats can be operated together or independently of each other. The wildcats are revolved in a horizontal plane, taking in each bower chain on the outboard side, and the port sheet chain on the inboard side of the port wildcat.

On the official trials of the vessel this windlass worked in a perfectly satisfactory manner.

STEERING ARRANGEMENT.

The steering gear is located aft in the compartment provided for it, and is of the standard type of the Bureau of Construction and Repair, consisting of a right-and-left-hand screw with traversing ends direct connected by side rods with crosshead on the rudder stock. The weight of the rudder is transmitted to this crosshead by means of a wrought-steel ring fitted in a groove near the head of the rudder stock. Between the crosshead and the casting on the stern post, a floating disk of phosphor-bronze is fitted, recessed in the stuffing-box casting, to hold oil, the weight of the rudder being taken by this floating ring. The casting bolted to the stern post and taking the weight of the rudder through this floating ring is fitted with a stuffing box around the rudder head capable of adjustment from a convenient location in the steering-engine room. A friction band is fitted to the rudder stock and is operated from the steering-engine room.

The steering engine is of sufficient power to put the rudder from hard aport to hard astarboard in twenty seconds when the vessel is moving ahead at full speed, with a working

steam pressure of 150 pounds per square inch. The engine is of sufficient strength, however, to withstand operation under the full boiler power. Provision is made in the steering-engine room for hand steering by wheels on a shaft geared to the main screw shaft. A slip joint is provided between the engine and the screw shaft to take up the lateral motion. Direct hand steering is provided for, in an emergency, by suitable arrangement of relieving tackles direct connected to the crosshead on the rudder stock. The hand-steering wheels are arranged to be thrown out of gear when the engine is at work, and to work readily through the main shaft with the engine out of gear.

PROPELLING MACHINERY.

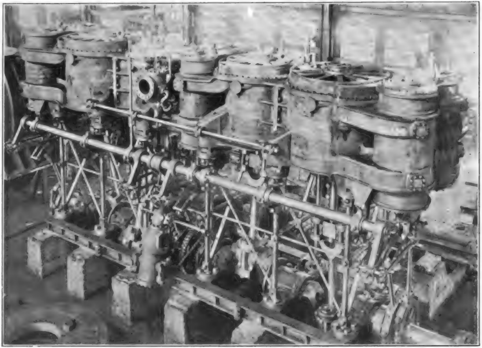
The propelling engines are right-and-left, and are placed in watertight compartments separated by an athwartship bulkhead.

The engines are of the vertical, inverted-cylinder, direct-acting, triple-expansion type.

The order of the cylinders, beginning forward, are forward low pressure, high pressure, intermediate pressure and after low pressure. The forward low-pressure and high-pressure cranks are opposite, also the intermediate and after low-pressure cranks, the second pair being at right angles with the first. The sequence of cranks will then be: high pressure, intermediate pressure, forward low-pressure and after low pressure.

The main valves are worked by Stevenson link motions with double-bar links. There is one piston valve for the high-pressure cylinder and two each for the intermediate and low-pressure cylinders.

The frame of the engines consists of forged-steel columns trussed by forged-steel stays. The engine bedplates are of cast steel, supported on the keelson plates. All crank, thrust, line and propeller shafting is hollow. The shafts, piston rods, connecting rods and working parts generally are of forged steel.



ENGINES, U. S. S. "BIRMINGHAM."

REVERSING GEAR.

The reversing gear for each engine consists of a steam cylinder and an oil-controlling cylinder fulcrumed in bearings on the bedplate. The common piston rod of the reversing-gear cylinders acts directly on a forked arm, keyed to the reversing shaft. The piston rod passes through the controlling cylinder with uniform diameter. The valve of the steam cylinder is of the piston pattern, of composition, worked by a continuation of the stem of the steam piston valve. These valves are worked by a floating lever, the primary motion being derived from the hand lever on the working platform, and the secondary motion from the reversing shaft, all parts being so adjusted that the reversing shaft follows the motion of the hand lever and is firmly held when stopped.

A pump for reversing by hand is connected to the oil cylinder, with its lever convenient to the working platform. The by-pass pipes are connected to the valve box of the hand pump in such a way as to leave the hand arrangements always in gear. The piston of the oil cylinder is packed by two cup leathers.

The following are the principal dimensions:

Steam cylinder, diameter, inches	14
Oil cylinder, diameter, inches	8½
Stroke, inches	18

REVERSING SHAFT.

There is one reversing shaft for each engine with an axial hole through it. It has arms for reversing gear and for each link. Each reverse arm for the links is made with a slot fitted with a block, to which the expansion links are attached. Each block is adjustable in the slot of its arm by a screw and handwheel with approved locking device, and is fitted with suitable index. The slot in these arms is so arranged that the links may always be thrown into full backward gear irrespective of the position of the block in the slot; and the length of the slot is such that the cut-off may be varied from about 0.5 to 0.75 of the stroke.

TURNING ENGINES AND GEAR.

There is in each engine room a double engine for turning the main engines with steam of 100 pounds pressure. This engine drives, by worm gearing, a second worm which may be made to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves, and are made reversible by means of a change valve moved by a screw and handwheel. Each engine is fitted for turning by hand.

PROPELLERS.

There are two 3-blade propellers, both outboard turning for ahead motion.

The bolt holes in the flanges of the blades are made oval, to allow of adjustment of the pitch, and each blade is firmly bolted to the hub by tap bolts, secured from turning by lock plates.

The dimensions of the propellers are as follows:

Diameter, feet and inches	12–06
Pitch, as set, mean, feet and inches	15–03
adjustable from, feet and inches 14–06 to	16–06
Ratio of diameter to pitch $\left(\frac{P}{D}\right)$	1.22
Area, projected, square feet	40.8
helicoidal, square feet	49.437
disk, square feet	122.72
Height of lower tip of blade above keel, inches	13
Immersion of upper tip of blade at low draught, inches	46⅜

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	28½
I.P., diameter, inches	45
F.L.P., diameter, inches	62
A.L.P., diameter, inches	62
stroke of all pistons, inches	36
Valves, H.P., one for each cylinder, diameter, inches	16¼
I.P., two for each cylinder, inches	18½
L.P., two for each cylinder, inches	25
Travel of valve, H.P., inches	9
I.P., inches	9
F.L.P., inches	9 $\frac{61}{64}$
A.L.P., inches	9 $\frac{31}{32}$
Connecting rod, length between centers, inches	72
ratio to crank	4 to 1

Crank shaft, number of sections	2
diameter, inches	$12\frac{3}{8}$
length, feet and inches, starboard	$13\text{-}08\frac{1}{4}$
port	$13\text{-}01\frac{1}{2}$
Crank pin, diameter, inches	$13\frac{1}{2}$
length, inches	$17\frac{1}{2}$
Thrust shaft, diameter, inches	$11\frac{1}{2}$
length, feet and inches, starboard	$20\text{-}00\frac{3}{4}$
port	$14\text{-}06\frac{1}{4}$
Line shaft, diameter, inches, starboard	$11\frac{1}{2}$
Stern-tube shaft, diameter, inches	$12\frac{1}{2}$
length, feet and inches	$35\text{-}10\frac{3}{4}$
Propeller shaft, diameter, inches	$12\frac{1}{2}$
length, feet and inches	$47\text{-}06\frac{3}{4}$

CONDENSERS.

Main Condensers.—There is one main condenser in each engine room, cylindrical in form, the inside diameter being 6 feet. The shell is $\frac{5}{16}$ inch thick, with three double-butt joints, with circumferential L-bar stiffeners. The water chests are cast composition $\frac{1}{2}$ inch thick. The forward chest is the one for the entrance and exit of circulating water, and has a division plate fitted with valves which, when open, allow the circulating water to pass overboard direct, the valves being worked by a lever on the outside of the condenser. It has nozzles for inlet and outlet of circulating water $16\frac{1}{2}$ inches in diameter. There are 4,085 seamless-drawn tubes in each condenser, $\frac{5}{8}$ inch outside diameter, No. 16 B.W.G. in thickness. The tubes are 12 feet long between tube sheets, and are spaced $\frac{13}{16}$ inch between centers. Baffle plates are fitted to direct the steam over all the tubes. The cooling surface for each condenser is about 8,000 square feet, measured on the outside of the tubes. The material of the condenser is as follows: Shells, steel, class B boiler plate; baffle plates, steel, class C boiler plate; tubes, composition—copper 70, tin 1, zinc 29 per cent.; tube sheets and supporting plates are of rolled Naval bronze; glands are of tubing of the same composition as the tubes; water chests are of composition; all plates are of bronze.

Auxiliary and Dynamo Condensers.—In the forward engine room there is an auxiliary condenser connected

through the auxiliary exhaust pipe to all the auxiliary machinery. The condenser has an air and a circulating pump.

In the dynamo room there is an auxiliary condenser for the exclusive use of the dynamo engines. It has an air and a circulating pump.

The shells of all condensers are $\frac{1}{4}$ inch thick; the tube sheets are 1 inch thick.

The diameter and the spacing of the tubes and the packing is the same as in the main condensers.

EVAPORATING AND DISTILLING PLANT.

There are four evaporators and four distillers with their accessories. The evaporators have a combined capacity of 16,000 gallons of water per twenty-four hours, and the distillers of 16,000 gallons of potable water per twenty-four hours.

The evaporators take steam from the auxiliary steam pipe, and the coil drain pipes lead through by-pass automatic traps to feed tanks. The shells of the evaporators have connections with valves and pipes of approved size, for directing the steam into the distillers and into the auxiliary exhaust pipe.

The feed water for the evaporators is taken from the circulating pipe after it has passed from distillers and from the sea.

There are blow pipes of ample size so arranged that the brine in the evaporators may be blown overboard.

The distiller circulating pumps discharge to the distillers, the water passing overboard. There is also a direct connection from these pumps to the sanitary pipe, and the relief valve for the distillers is so placed as to act for both the distillers and the sanitary pipe.

In addition to the pump connection for distiller circulating, provision is made for circulating water through the distillers.

The evaporators are horizontal, and each has 223 square feet of tube-heating surface. The tubes are 2 inches outside diameter and are without bends.

Each distiller has 80 square feet of tube-cooling surface. The tubes are straight, $\frac{5}{8}$ inch outside diameter, thor-

oughly tinned on both sides, and expanded and sweated into tube sheets.

FEED-WATER HEATERS.

In each engine room there is a feed-water heater with all necessary fittings complete. The cooling surface for each heater is 600 square feet, measured on the outside of the tubes.

The heater is of the direct-flow type located on the discharge side of the main feed pumps. The heating agent is auxiliary exhaust steam.

The tubes are ⅝ inch outside diameter, of No. 16 B.W.G.

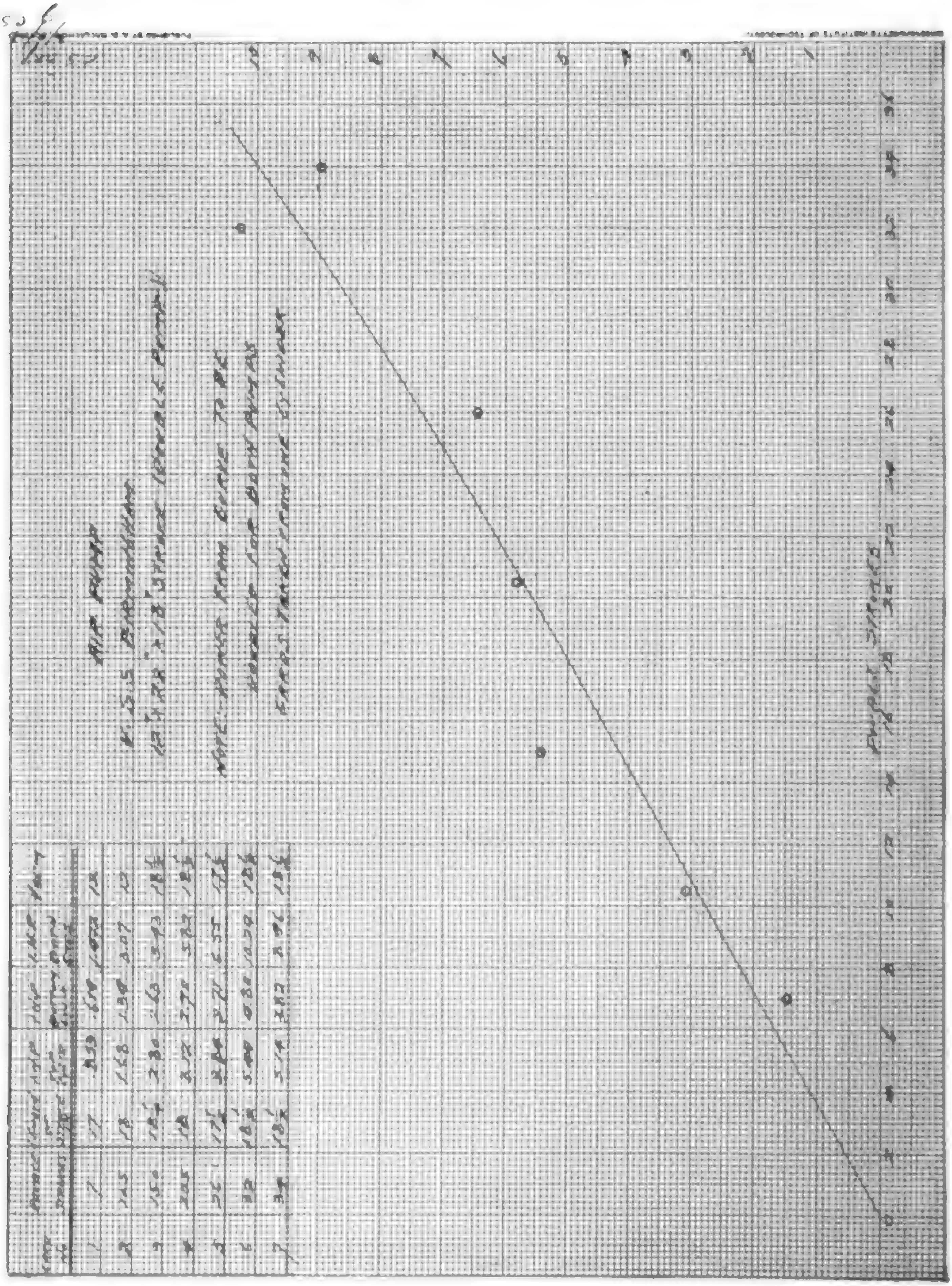
PUMPS.

The pumps are in accordance with the following table:

DATA OF PUMPS AND AUXILIARY ENGINES.

Auxiliary pumps.	Number.	Type, make and location.	Steam cylinders.				Water cylinders.			
			Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.	Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.
Main air	2	Blake vertical duplex, one in each engine room	2	12	2½	18	2	[illegible]	2½	18
Main circulating	2	Centrifugal, driven by 8" and 15" × 8" vert. com. engine, one in each engine room.	2	8 x 16	1½	8	...	...	...	...
Main feed	2	One Blake vertical simplex in each engine room.	1	15	2¼	15	1	10	2¼	15
Auxiliary feed	3	One Blake vertical simplex in each fireroom.	1	9	1¾	12	1	6	1⅜	12
Engine-room fire and bilge	2	One Blake vertical simplex in each engine room.	1	10	1¾	12	1	8½	1½	12
Reserve feed	1	One Blake vertical simplex in forward engine room.	1	3½	⅞	4	1	4	⅞	4
Auxiliary condenser	1	Blake horizontal simplex combined air and circulator in forward engine room.	1	6	1¼	12 Air,	1 1	10 10	1¼ 1¼	12 12
Dynamo condenser	1	Blake horizontal simplex combined air and circulator in dynamo room.	1	6	1¼	11 Air,	1 1	8 8	1¼ 1¼	12 12
* Evaporating and distilling plant.	2	Dist. circ. horiz. simp., Orlop deck.	1	10	1¼	12	1	10	1¼	12
	1	Evap. feed vert. simp., Orlop deck.	1	4½	1⅛	6	1	5	1⅛	6
	1	Fresh-water vert. simp., Orlop deck.	1	4½	1⅛	6	1	5	1⅛	6
Fireroom fire and bilge	3	One Blake vertical simplex in each fireroom.	1	12	2	12	1	8	2	12

* Maximum rated output of fresh water (distilled) per 24 hours, 16,000 gallons.


AIR PUMP
U.S.S. BIRMINGHAM

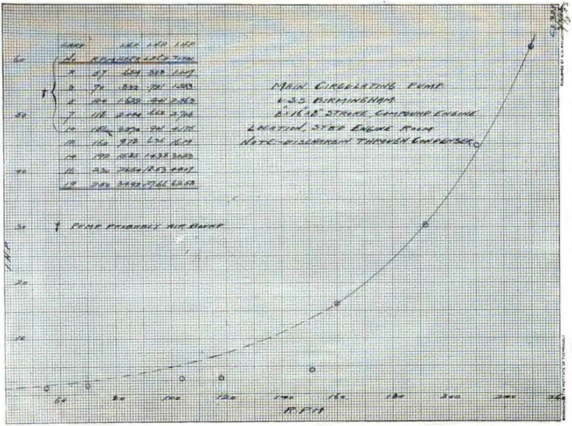

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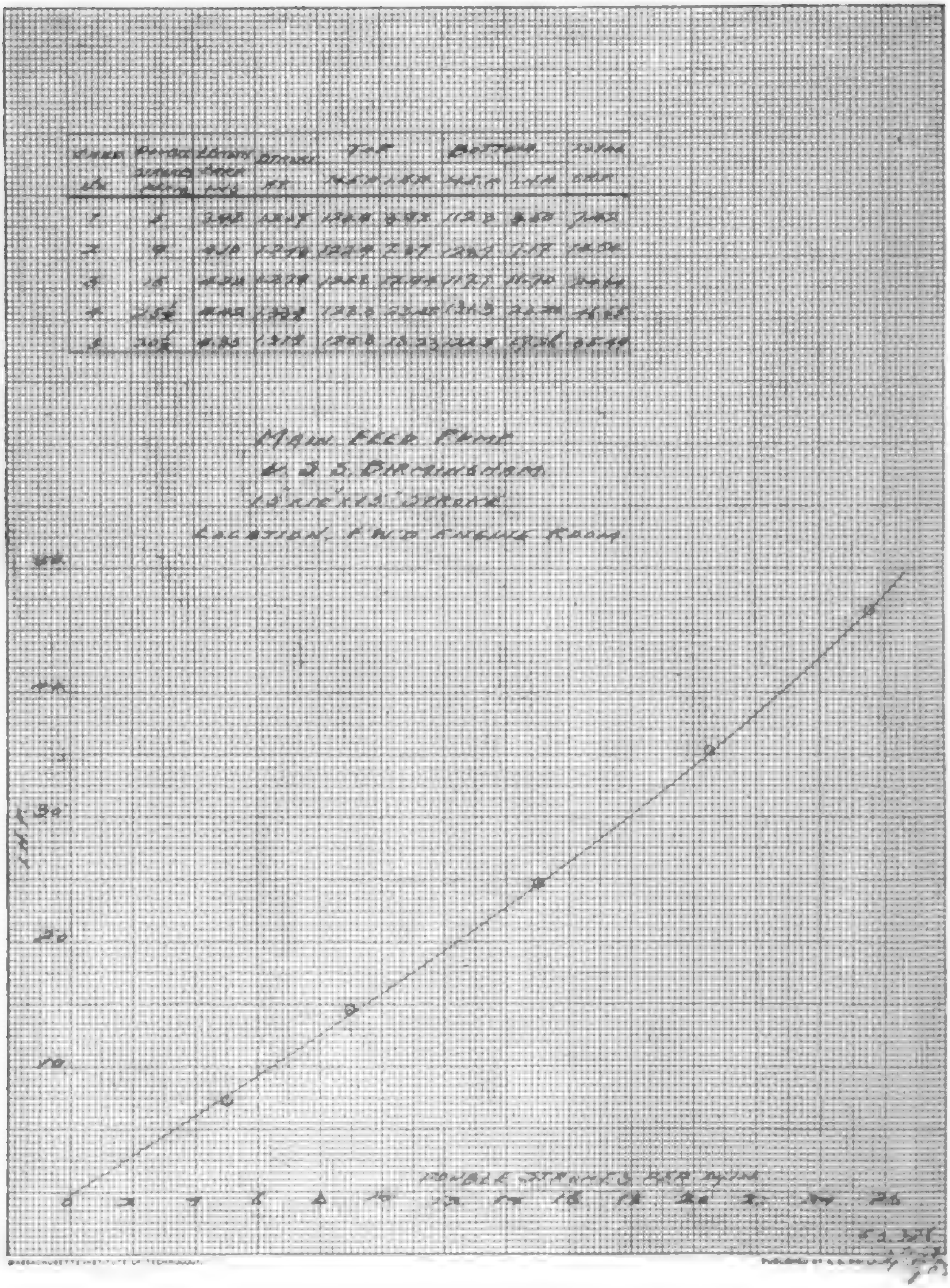
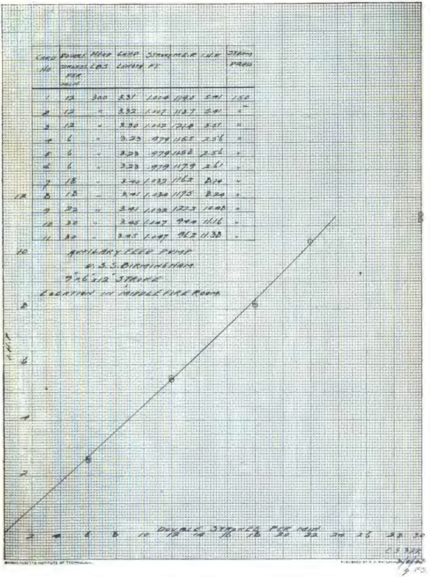
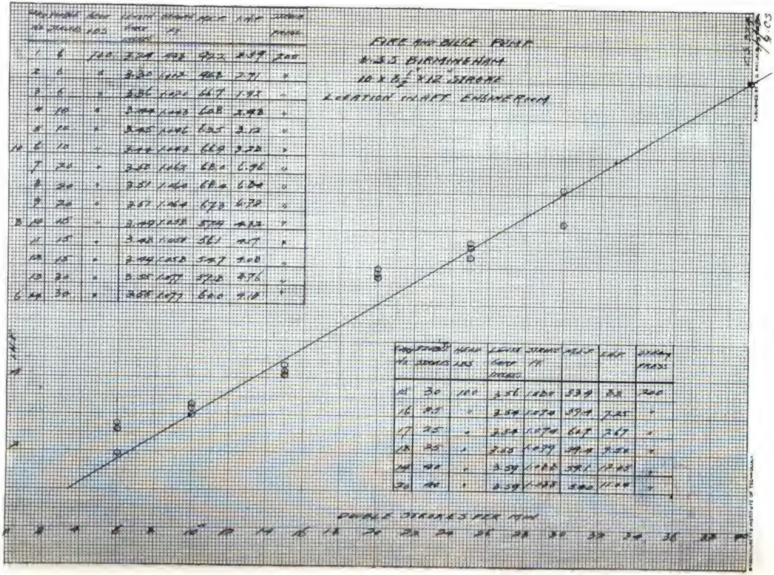
FIG. 57
MAIN CIRCULATING PUMP
U.S.S. BIRMINGHAM
8"×16"×8" STROKE, COMPOUND ENGINE
LOCATION, STBD ENGINE ROOM
NOTE—DISCHARGE THROUGH CONDENSER
CARD No. | R.P.M. | I.H.P. H.P. CRANK | I.H.P. L.P. CRANK | I.H.P. TOTAL
4 | 27 | .654 | .393 | 1.047
6 | 70 | .832 | .721 | 1.553
8 | 104 | 1.638 | .744 | 2.382
7 | 118 | 2.044 | .662 | 2.706
10 | 168 | 3.374 | .901 | 4.275
13 | 160 | 9.78 | 6.36 | 16.14
14 | 190 | 15.85 | 14.38 | 30.23
16 | 230 | 26.54 | 18.53 | 44.07
19 | 250 | 34.92 | 27.66 | 62.58
† PUMP PROBABLY AIR BOUND
†
I.H.P.
60
50
40
30
20
10
60
80
100
120
140
160
180
200
240
260
R.P.M.


Main Feed Pump
U. S. S. Birmingham



CARD No	DOUBLE STROKES PER MIN	HEAD LBS	CARD LENGTH	STROKE FT	M.E.P	I.H.P	STEAM PRES
1	12	300	3.31	1.024	119.3	5.41	1.50
2	12	"	3.32	1.107	113.7	5.41	"
3	12	"	3.30	1.032	121.4	5.51	"
4	6	"	3.23	.979	116.5	2.56	"
5	6	"	3.23	.979	115.6	2.56	"
6	6	"	3.23	.979	117.9	2.61	"
7	18	"	3.40	1.037	116.2	8.14	"
8	18	"	3.41	1.034	117.5	8.24	"
9	22	"	3.41	1.032	122.3	10.40	"
10	30	"	3.05	1.147	94.4	11.16	"
11	30	"	3.45	1.047	96.2	11.30	"

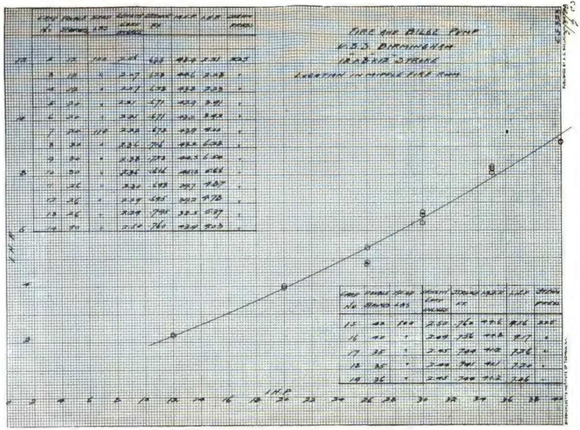
AUXILIARY FEED PUMP
U. S. S. BIRMINGHAM
7" × 6" × 12" STROKE
LOCATION IN MIDDLE FIRE ROOM



FIRE AND BILGE PUMP
U.S.S. BIRMINGHAM
10 × 8½ × 12" STROKE
LOCATION IN AFT ENGINE ROOM

Exp. No.	Double Strokes	Head Lbs	Length Card Inches	Stroke Ft	M.E.P.	I.H.P.	Steam Press.
1	6	100	3.24	.998	42.2	2.37	200
2	6	"	3.30	1.002	46.8	2.71	"
3	6	"	3.36	1.020	66.7	1.92	"
4	10	"	3.44	1.043	62.8	2.98	"
5	10	"	3.45	1.046	63.5	3.12	"
6	10	"	3.44	1.043	66.9	3.32	"
7	20	"	3.50	1.063	68.0	6.76	"
8	20	"	3.51	1.060	68.0	6.84	"
9	20	"	3.67	1.064	67.3	6.72	"
10	15	"	3.49	1.058	57.9	4.32	"
11	15	"	3.48	1.058	56.1	4.17	"
12	15	"	3.49	1.058	54.7	4.08	"
13	30	"	3.55	1.077	57.8	8.76	"
14	30	"	3.55	1.077	60.0	9.18	"

Exp. No.	Double Strokes	Head Lbs	Length Card Inches	Stroke Ft	M.E.P.	I.H.P.	Steam Press.
15	30	100	3.56	1.080	53.4	8.8	200
16	25	"	3.54	1.070	59.4	7.25	"
17	25	"	3.54	1.070	66.7	7.67	"
18	25	"	3.55	1.079	59.4	7.50	"
19	40	"	3.59	1.088	57.1	12.45	"
20	40	"	3.59	1.088	54.0	11.44	"


FIRE AND BILGE PUMP
U.S.S. BIRMINGHAM
[illegible] STROKE
LOCATION IN [illegible] FIRE ROOM
I.H.P.
0
2
4
6
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16
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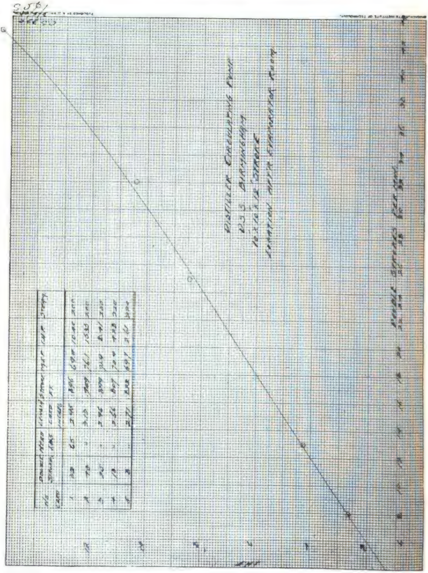
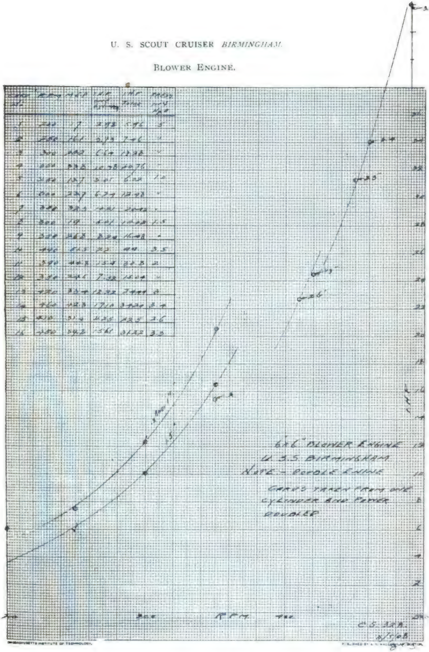
40



No. Card	Double Strokes	Head Lbs	Length Card inches	Stroke Ft	M.E.P.	I.H.P.	Steam
1	32	65	2.95	.896	69.8	10.86	200
2	28	"	3.13	.909	76.1	15.35	200
3	25	"	2.96	.879	71.9	8.41	200
4	18	"	2.56	.807	70.4	4.72	220
5	8	"	2.71	.822	69.7	2.61	220

U. S. SCOUT CRUISER *BIRMINGHAM.*

BLOWER ENGINE.



Card No.	R.P.M.	M.E.P.	I.H.P. per cylinder	I.H.P. Total	Press. per sq. in.
1	200	7	2.98	5.96	5
2	250	16.1	3.73	7.46	"
3	300	22.2	6.64	13.28	"
4	350	33.5	10.38	20.76	"
5	300	13.7	3.01	6.02	1.0
6	400	22.7	6.24	12.48	"
7	350	35.3	9.81	20.02	"
8	200	19	5.01	10.02	1.5
9	320	46.8	8.04	16.08	"
10	440	61.5	22	44	3.5
11	390	44.8	15.4	32.8	2
12	320	26.6	7.32	15.04	"
13	480	33.4	12.82	24.44	3
14	460	48.3	17.10	34.20	3.4
15	500	31.4	11.25	22.5	2.6
16	450	39.2	15.61	31.22	3.5

6×6" BLOWER ENGINE
U.S.S. BIRMINGHAM
NOTE – DOUBLE ENGINE
CARDS TAKEN FROM ONE CYLINDER AND POWER DOUBLED

C.S. 3RB.
3/5/08.

BOILERS.

There are twelve water-tube boilers of the Fore River type, placed in three watertight compartments.

The steaming capacity is such that all steam machinery on board can be run at full power with an average air pressure in the firerooms of not more than five inches of water. The following list gives the particulars of these boilers:

Length, external, feet and inches	11-02
Width, external, feet and inches	12-00½
Number of furnaces	1
Grate surface, one boiler, square feet	58
Heating surface, one boiler, square feet	3,166
Grates, length, feet	7.25
width, feet	8
Pressure, design, working, pounds	275
test, pounds	400
Ratio G.S. to H.S	54.6
Number of tubes, one boiler	1,462

REFRIGERATING PLANT.

There are two Allen dense-air ice machines, each capable of producing the cooling effect of one ton of ice per day. The cooling pipes from the machine lead into the ice tank, scuttle butt and the cold-storage room.

Valves are provided in accordance with the Bureau of Steam Engineering standard arrangement of valves in cold pipes for refrigerating plant, so that the air may go to the cold-storage room direct, or through the ice-making tank and thence to the cold-storage room and scuttle butt, and also from the ice-making tank direct to the scuttle butt.

Refrigerating machines are operated by steam engines.

OFFICIAL TRIALS.

Standardization of Screws.—The vessel was tried by the standardized screw method, progressive runs being made over the measured mile off Rockland, Maine, March 11, 1908. During the trial the weather was fair with a smooth to a moderate sea.

From the data obtained on these runs the curves shown on Plate I were plotted.

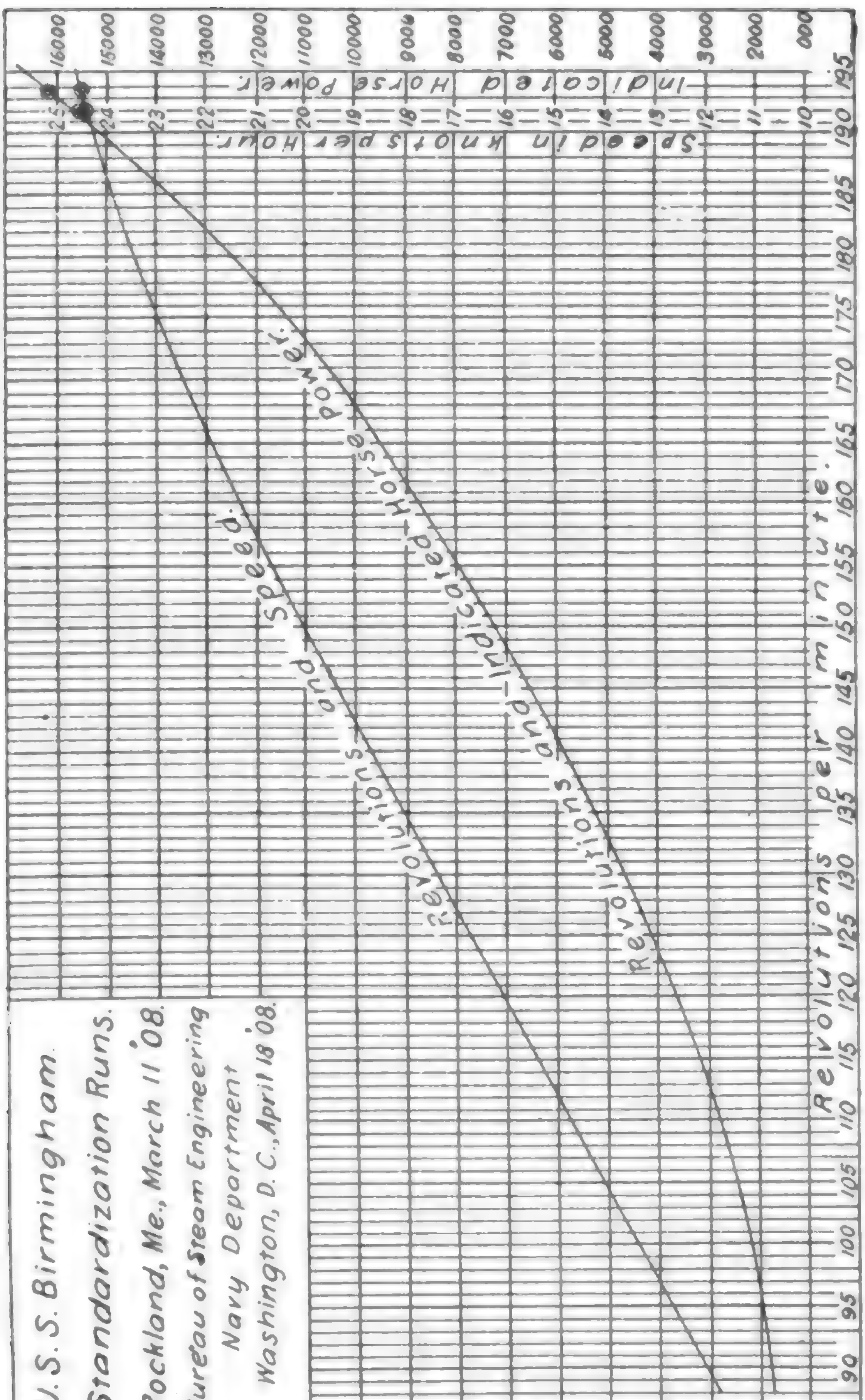

U.S.S. Birmingham.
Standardization Runs.
Rockland, Me., March 11 '08.
Bureau of Steam Engineering
Navy Department
Washington, D.C., April 18 '08.
Revolutions and Speed.
Revolutions and Indicated Horse power.
Revolutions per minute.
Speed in knots per hour
Indicated Horse power

Plate I.

It was determined that a mean of both engines of 89.7 revolutions per minute was required for a true speed of 12 knots; 170.38 revolutions per minute for a speed of 22.5 knots; and 187.23 revolutions per minute for a true speed of 24 knots. The draught and corresponding displacement at the beginning and end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	16-02$\frac{5}{8}$	15-11$\frac{1}{4}$
aft, feet and inches	17-02$\frac{1}{2}$	17-01$\frac{5}{8}$
Displacement, tons	3,757	3,701

OFFICIAL FOUR-HOURS' TRIAL.

On March 12, 1908, the four-hours' official trial in the open sea, as prescribed by the contract, was held. The draught and corresponding displacement at the beginning and end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	16-08$\frac{1}{4}$	16-03$\frac{3}{4}$
aft, feet and inches	16-09$\frac{3}{8}$	16-08$\frac{7}{8}$
Corresponding displacement, tons	3,768	3,676

The data obtained on this trial were as follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	250	
engines, pounds	238.0	230.0
H.P. steam chest gauge, pounds	221.0	229.0
1st receiver (absolute), pounds	92.4	97.6
2d receiver (absolute), pounds	26.3	27.1
Vacuum in condensers, inches of mercury, mean	26.6	26.3

Temperatures. (Average of one-half hourly observations.)

	Starboard.	Port.
Injection, degrees	37	
Discharge, degrees	104.0	105.0
Hotwell, degrees	99.0	98.0
Feed water, degrees	185.0	174.0
Engine room, working platform, degrees	83.0	78.0
Firerooms, working level, degrees	81.0	
Smoke stacks, average, degrees	665.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Average revolutions, main engines, per minute	192.96	190.35
Pumps, main air	22.7	21.4
circulating	180.0	182.0
feed, d.s., per minute	38.4	31.0
fire and bilge	...	25.0
Dynamos, engines	400	
Blower engines	430	
Speed of ship, in knots per hour	24.326	
Slip of propeller, in per cent. of its own speed, based on mean pitch	16.40	15.23
Air pressure in firerooms, in inches of water, mean	2.54	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	109.4	107.7
I.P. cylinder	46.1	47.1
F.L.P. cylinder	11.5	11.9
A.L.P. cylinder	17.4	13.7
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	37.5	36.2

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	2,349.0	2,285.0
I.P. cylinder	2,551.0	2,571.0
F.L.P. cylinder	1,212.0	1,241.0
A.L.P. cylinder	1,833.0	1,434.0
total	7,945.0	7,531.0
Collective H.P. of both main engines	1,5476.0	
Main air, circulating and feed pumps	194.0	
Other auxiliaries	219.0	
Total	15,889.0	

COAL.

Kind and quality used on trial	Pocahontas, run of mine.
Pounds, per hour, main and auxiliary engines, during trial	2,990.4

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	22.83
Pounds of coal per I.H.P. per hour, main engines	1.932
all machinery in operation	1.882
square foot of grate surface per hour	42.96
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.032
Heating surface, square feet per I.H.P. (total)	2.39

OFFICIAL TWENTY-FOUR HOURS' TRIAL.

On March 12, 1908, the official twenty-four hours' trial at 12 knots was commenced. The weather during this trial was fair the first part but became overcast and threatening during the latter part. The wind was very moderate to stiff breezes from the N. to S.S.E. and S. The sea was moderate.

The data obtained on this trial were as follows:

PERFORMANCE.—TWENTY-FOUR HOURS' OFFICIAL TRIAL AT TWELVE KNOTS.

Steam Pressures. (Average of one-half hourly observations.)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	206.0	
engines, pounds	205.0	199.0
H.P. steam-chest gauge, pounds	49.0	54.0
1st receiver (absolute), pounds	19.0	24.0
2d receiver (absolute), pounds	5.80	7.60
Vacuum in condensers, inches of mercury, mean	26.4	27.1

Temperatures. (Average of one-half hourly observations.)

	Starboard.	Port.
Injection, degrees	38.2	39.3
Discharge, degrees	50.0	62.3
Hotwell, degrees	102.0	...
Feed water, degrees	183.0	...
Engine room, working platform, degrees	75.5	85.1
Smoke stacks, average, degrees	352.0	

Revolutions, or double strokes, per minute. (Average of one-half hourly observations.)

	Starboard.	Port.
Average revolutions, main engines, per minute	91.40	91.26
Pumps, main air	17.4	16.5
circulating	151.6	109.0
feed, d.s., per minute	15.0	...
Dynamos	400.0	
Blower engines	262.0	
Speed of ship, in knots per hour	12.225	
Slip of propeller, in per cent. of its own speed, based on mean pitch	11.30	11.23
Air pressure in firerooms, in inches of water, mean	0.25	

Mean Effective Pressures in Cylinders, in pounds per square inch. (Averages of cards taken at half-hourly periods.)

	Starboard.	*Port.*
Main engines, H.P. cylinder	34.0	35.8
I.P. cylinder	8.6	12.2
F.L.P. cylinder	1.48	1.4
A.L.P. cylinder	2.01	2.03
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	7.61	8.58

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	344.0		365.0
I.P. cylinder	226.0		317.0
F.L.P. cylinder	74.0		69.0
A.L.P. cylinder	100.0		101.0
total	744.0		852.0
Collective H.P. of both main engines		1,596.0	
main air, circulating and feed pumps		54.0	
Other auxiliaries		103.0	
Total		1,753.0	

COAL.

Kind and quality used on trial..............................Pocahontas, run of mine.
Pounds, per hour, main and auxiliary engines during trial.............. 4,629.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	7.56
Pounds of coal per I.H.P. per hour, main engines	2.90
all machinery in operation	2.64
square foot of grate surface, per hour	19.95
Cooling surface (main condenser), square feet per I.H.P. (main engines	10.01
Heating surface, square feet per I.H.P. (total)	7.22

OFFICIAL TWENTY-FOUR HOURS' TRIAL, AT TWENTY-TWO AND ONE-HALF KNOTS PER HOUR.

On March 14, 1908, the twenty-four hours' official trial at $22\frac{1}{2}$ knots per hour, according to contract, was commenced. The weather during this trial was at first fair, but foggy and overcast during the latter part. The wind was at first light, but gradually increased to a stiff breeze, developing a moderate sea and swell.

The data obtained on this trial were as follows:

47

PERFORMANCE.—TWENTY-FOUR HOURS' OFFICIAL TRIAL AT TWENTY-TWO AND ONE-HALF KNOTS.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Mean steam pressure at boilers, pounds	203.0	
engines, pounds	192.0	181.0
H.P. steam chest gauge, pounds	171.0	178.0
1st receiver (absolute), pounds	67.6	77.2
2d receiver (absolute), pounds	20.0	22.6
Vacuum in condensers, inches of mercury, mean	27.0	27.1

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	39.5	...
Discharge, degrees	102.0	105.0
Hotwell, degrees	99.0	...
Feed water, degrees	177.0	168.0
Engine room, working platform, degrees	78.2	...
Smokestacks, average, degrees	554.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	172.2	172.0
Pumps, main air	23.1	21.2
circulating	160.6	145.4
feed, d.s., per minute	30.0	30.0
fire and bilge	...	19.5
Dynamos	400.0	
Blower engines	404.0	
Speed of ship, in knots per hour	22.668	
Slip of propeller, in per cent. of its own speed, based on mean pitch	12.71	12.59
Air pressure in firerooms, in inches of water, mean	1.98	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	90.3	89.9
I.P. cylinder	35.2	37.8
F.L.P. cylinder	8.61	9.3
A.L.P. cylinder	9.78	10.72
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	27.69	29.09

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P. cylinder	1,743.0	1,739.0
I.P. cylinder	1,748.0	1,876.0
F.L.P. cylinder	814.0	878.0
A.L.P. cylinder	937.0	1,016.0
total	5,242.0	5,509.0
Collective H.P. of both main engines	10,751.0	
main air, circulating and feed pumps	166.0	
Other auxiliaries	181.0	
Total	11,098.0	

COAL.

Kind and quality used on trial..............................Pocahontas, run of mine.
Pounds, per hour, main and auxiliary engines, during trial......... 20,510.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	15.945
Pounds of coal per I.H.P. per hour, main engines	1.908
all machinery in operation	1.848
square foot of grate surface, per hour	29.47
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.485
Heating surface, square feet per I.H.P. (total)	3.423

SERVICE TEST ON THE STEAMSHIP *GOVERNOR COBB.**

(PARSONS TURBINE.)

By W. S. Leland and H. A. Everett.

The test on the steamship *Governor Cobb*, of the Eastern Steamship Company, was run by the Massachusetts Institute of Technology to provide thesis work for some of the graduates in the Department of Naval Architecture.

The test was run under service conditions on the regular trip of the *Cobb* from Boston to St. Johns, *via* Portland and Lubec. Observations began on passing Boston Light and were continued for twenty-six hours—for the boiler test continuously; for the engine test at favorable times.

All observations were plotted, which presents an interesting study of the results and makes simultaneous readings possible with a limited corps of observers. The close agreement of these curves is a good check on the accuracy of the observations.

Time has not permitted the preparation of a complete report, but merely a summary of that portion of the test run at full speed under the most favorable conditions.

The horsepower was determined by means of the Denny and Johnson torsion meter belonging to the United States steamship *Chester*, which was loaned by the Bureau of Steam Engineering, United States Navy Department, through the courtesy of Admiral Charles W. Rae, Chief of the Bureau. The details of the loan were arranged by Benjamin C. Bryan, Lieutenant Commander, U. S. N., who gave the matter his personal attention and accompanied our party on the test.

* Reprinted from "Transactions of the Society of Naval Architects and Marine Engineers," 1907, 15, 117-120, plates 37-39. Copyrighted.

The torsion meter was set up in the engineering laboratory and a thorough working knowledge obtained by the use of experimental apparatus before installing the meter on board. Thirty-six feet on the side shafts, and 49 on the center shaft between inductors, was the greatest length obtainable, which gave a meter reading of about .50 and .73, respectively, at full power.

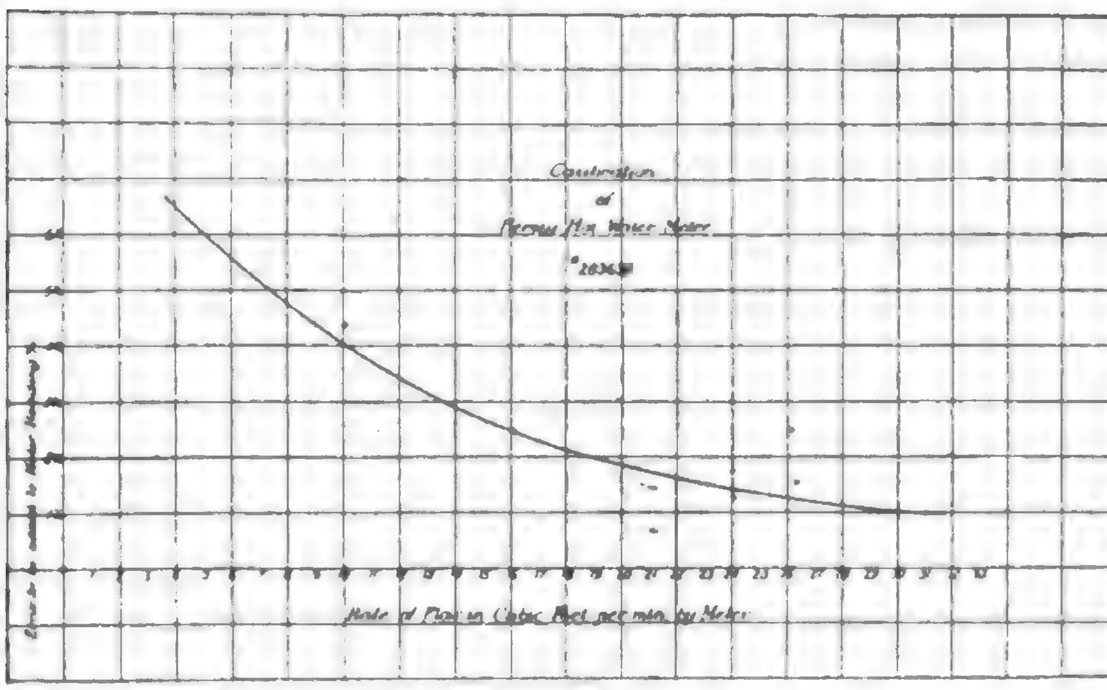


FIG. 1

In computing the horsepower, 1.506, based on an assumed torsional modulus of elasticity of 11,600,000, was used for the constant K in the formula:

$$\text{H.P.} = \frac{K d^4 r R}{C L},$$

in which $d =$ diameter of shaft in inches ($6\frac{3}{8}$).

$r =$ torsion meter reading.

$R =$ revolutions per minute.

$C =$ inductor constant (12.5).

$L =$ length of shaft in feet between inductors.

The water consumption was measured by a Hersey hot-water meter, loaned by the Hersey Manufacturing Company, of South Boston. It was installed in the suction line between the hot well and the feed pump, and gave exceedingly satisfactory results.

This meter was later calibrated under similar conditions, the curve in Figure 1 showing the percentages of error. The plot of meter readings was struck in as a straight line, showing practically a uniform rate of water consumption, no point varying from the line by a quantity greater than 1 per cent. of the total.

The steam for all auxiliary purposes was passed through the two auxiliary lines, one on each side of the vessel, and the quantity measured by its flow through orifices. A thin steel plate, having a hole $1\frac{5}{16}$ inches in diameter, was inserted in each auxiliary line between two flanges near the boiler. Pressures were read simultaneously at both orifices and at no time showed a variation of over a pound after making the proper gauge corrections.

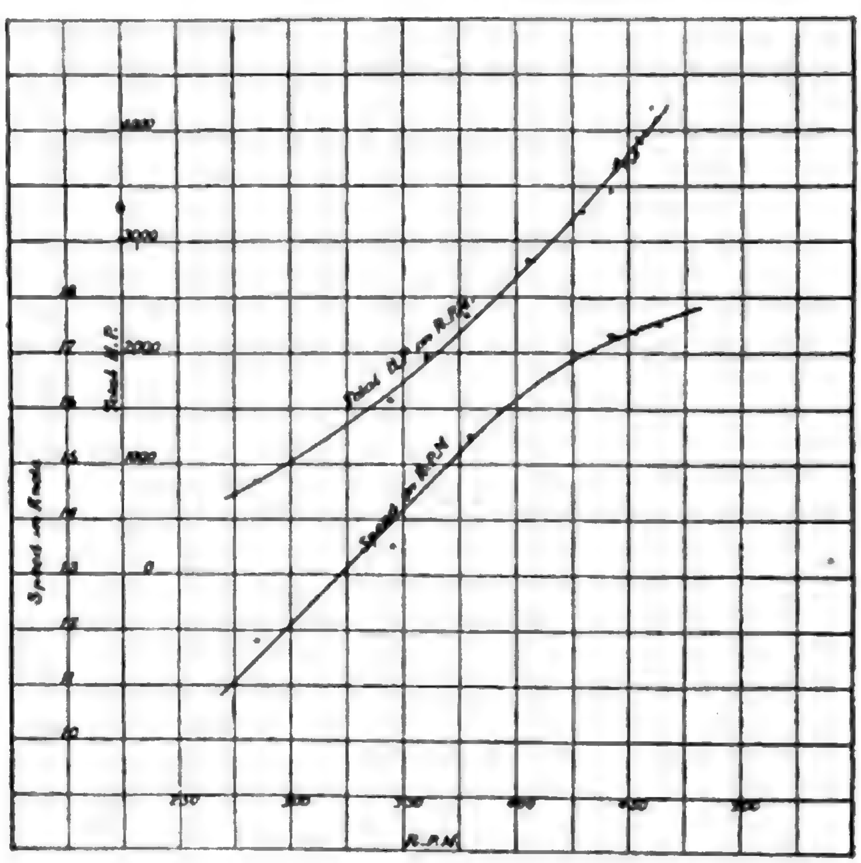


FIG. 2

The orifice was afterwards set up in the laboratory and its coefficient carefully determined by actually weighing the condensed steam under conditions similar to those on the boat.

Several buckets of coal were weighed and their average,

which varied only ten pounds from either maximum or minimum, multiplied by the number of buckets, was taken as the coal consumption. The plot of coal consumption, like that of the water, is a perfectly straight line, showing a uniform rate.

The run from Boston to Portland was largely consumed in a progressive trial, the speed being taken by a stop-watch and a McGray electric log towed from the end of a boom well clear of the wake. The log had previously been calibrated by towing over the measured mile.

Results of speed and power are shown in the curves in Figure 2.

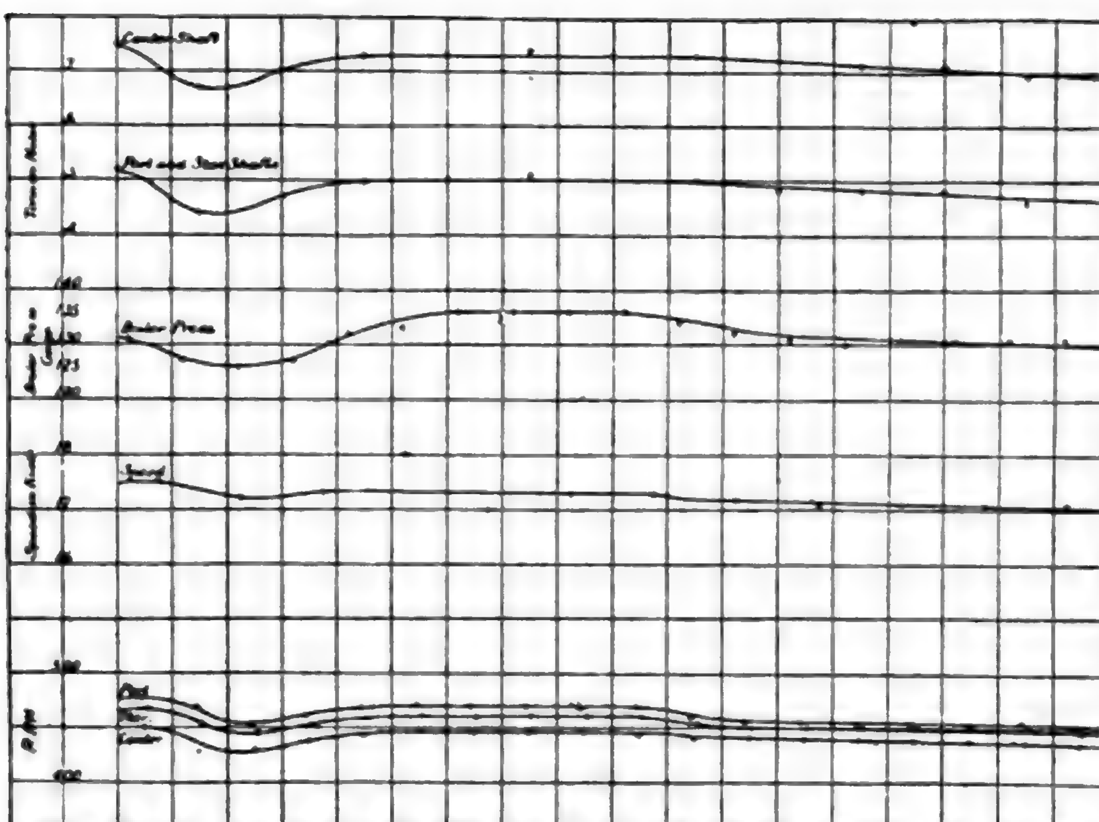


FIG. 3

The best run was made at full speed between Portland and Lubec, under the most favorable conditions of weather and sea. All observations were taken at ten-minute intervals excepting the coal, which was recorded every fifteen minutes. Figure 3 shows the chief records during this test.

An attempt was made to determine the quality of steam, but as there were objections to tapping the main pipe a sample was taken from the drip connection, which showed 2.5 per cent. of moisture, which is more than would be obtained from a fair sample. It may be of interest to compare the following tabulated results with similar results obtained from a test on the steamship *Nantucket*, of the Merchants' and Miners' Transportation Company.

RESULTS OF TEST.

	Nantucket.	*Cobb.*
Type of engine	Reciprocating.	Parsons Turbine.
Date of test	February 7, 1904.	April 18, 1907.
Duration of test, boiler, hours	20¼	8
engine, hours	20¼	4
Boiler pressure (average gauge) pounds	147.3	128
Vacuum, in inches	25	27
Quality of steam (sampled at drip)	98.8	97.3
Barometer, pounds	14.7	14.7
Temperature of air-pump discharge, degrees Fahrenheit	...	110
Temperature of feed water, degrees, Fahrenheit	209.4	213
Kind of coal used	Georges Creek.	Cape Breton.
Moisture in coal, per cent	2.0	1.9
Ash and clinker in coal, per cent	7.6	6.8
Draft at blowers, inches	Natural.	2.1
Number of boilers (single-ended Scotch)	4	6
Total grate surface, square feet	320	323
heating surface, approximately, square feet	10,150	12,000
Coal fired per hour, pounds	5,135	8,050
Water fed per hour (average during engine test), pounds	45,844	85,710
Coal burned per square foot grate surface, pounds	16	24.64
Maximum revolutions, port	...	475
starboard	...	460
center	...	450
Corresponding total shaft horsepower	...	4,100
Average revolutions	74.05	447
total horsepower	2,362 I.H.P.	3,747 S.H.P.

	Nantucket.	*Cobb.*
Steam for auxiliaries, pounds	...	38,360
per I.H.P. per hour, total pounds	19.41	...
shaft horsepower per hour for all purposes	...	22.67
Steam per shaft horsepower per hour (propelling machinery only), pounds.	...	19.74
Speed (average), knots	15.00	17.21

DIMENSIONS.

	Nantucket.	*Cobb.*
Length between perpendiculars, feet	274	290
Beam molded, feet	42	51
Draught, feet	15	13
Displacement, tons	2,700	...

NOTES.

THE WEIGHT OF MARINE TURBINES.

That the weight of marine turbine machinery has been greatly increased during the last two or three years is well known, and as the tendency is still towards increase without any proportionate gain in economy, it may be as well to examine the causes which have led up to this, and indicate some means whereby it can advantageously and safely be reduced. To some extent a considerable increase was necessary on account of the absolute unsuitability of the original marine installations to the commercial necessities of marine engineering. For instance, in many vessels the replacing of a broken gland ring, involving a few minutes' work in a reciprocating job, necessitated lifting the cylinder cover and rotor from the turbine. A large increase in weight of astern turbines was also necessary, the early turbine vessels being lamentably deficient in maneuvering power. More rigid cylinder and rotor construction was also desirable, and in the case of the new Cunarders and the ocean-going destroyers, it was found necessary greatly to increase the blade sections, as the stress in these, due more especially to end thrust, was exceptionally high. All this involved increase of weight for the same power and speed of rotation, and developments in propeller design involving greatly reduced revolutions added still more. For the same efficiency, the weight of a turbine of a given power will vary inversely as the square of the revolutions, so that a reduction from 500 to 400 revolutions per minute, brought about by the more advantageous use of a larger propeller, involves an increased weight of over 60 per cent. The use of much heavier cylinders than Parsons originally tried was due to substitution of cast iron for cast steel. Not only

were cylinders extremely hard to obtain in the latter metal—the *Amethyst* had numerous failures before a good one was secured—but cast steel has an awkward habit of warping, and distortion of cylinders has accounted for endless blade stripping. In warships the use of cruising turbines has greatly augmented the weight per horsepower. Lagging, thrust-adjustment gear, oil-cooling and pumping systems, outside glands with mazes of valves and pipes for a most complicated steam-packing system, are all items that have been enormously increased without attracting much notice. It is very simple to advocate reduction, but the fact is that in the early stages the marine turbine, whatever future promise it had in store in the eyes of those that were first acquainted with it, was a crude and undeveloped machine that needed a great deal of modification before it was made commercially suitable. That modification meant increasing the weight.

The following table gives the weights of turbine machinery only, excluding all auxiliaries, condensers, or shafting for various classes of vessel:

WEIGHT OF TURBINES PER HORSEPOWER.

Type of ship.	Shaft H.P.	Revolutions.	Weight of turbine, tons.	Weight per H.P., pounds.
Battleship	25,000	320	450	40.4
Ditto, proposed	28,000	275	540	43.2
Small cruiser	14,000	500	180	28.8
Torpedo-boat destroyer	18,000	700	80	10.0
Ditto	4,000	1,100	18	10.1
Channel steamer	12,000	500	110	20.5
Atlantic liner (type)	42,000	250	900	48.0
Intermediate steamer	10,000	350	180	40.25

That the present weight of machinery can be greatly reduced there can be no doubt whatever, but it involves a very much clearer appreciation of the functions and performance of the numerous details in an installation than now appears to be possessed in some quarters.

Commencing with the turbine cylinder, in nearly all cases do we find circumferential ribs of some kind; either the half-round rib, typical perhaps of East Coast practice, or the heavy

bulb rib that has distinguished Clyde cylinders for years. A turbine cylinder after all is a pipe in the position of a beam fixed at the after end and free to slide (supported) at the forward end. When working it is under gradually decreasing internal pressure. Who would rib a pipe, and if so, what use are bulb ribs if half-round ones do, as has been amply proved? What use, in any case, are the shallow half-round ribs? This, at least, is a point on which practice is not only not consistent, but not apparently correct in its policy from the beginning.

Then, again, take the test pressure enforced. Without mentioning names, we can quote instances of Admiralties or registration societies, acting doubtless on the recommendations of their technical advisers, who insist that a high-pressure cylinder shall be tested to one and a-half times the boiler pressure, and that the forward end of the low-pressure cylinder shall be tested to one-fifth the boiler pressure. "Escape valves will be fitted at the after end of the high-pressure cylinders," says the specification. Now, with a boiler pressure of 250 pounds this means that the cylinder end and the last expansion of the high-pressure have to withstand 375 pounds per square inch, while the end of the low-pressure and its first expansion, which, when working, are dealing with an identical pressure to that in the end of the high-pressure, have only to withstand 50 pounds per square inch. Assuming this turbine to be working between 185 pounds per square inch and 28 inches vacuum, the maximum working pressure in the receiver pipe will only be between atmosphere and 5 pounds gauge; so that even without the escape valve the test pressure is enormously exaggerated. This is another direction in which weight can be safely reduced by proper appreciation of the function of the various parts. The two cylinders effect the expansion of the steam in six stages in each—twelve in all, or, say, the first four correspond to the high-pressure cylinder, the last two in the high-pressure and first two in the low-pressure corresponding to the intermediate cylinder of a reciprocating engine. Even in the days of 300 pounds pres-

sure and Belleville boilers, no one was found to require a water-pressure test of more than 200 pounds per square inch on an intermediate cylinder, or only about half what the much larger turbine barrel has to stand. These high test pressures, quite apart from adding to weight, are objectionable on the grounds of causing permanent deflection in the castings. It is consequently never possible to put this pressure on after the cylinders have been finished in the boring machine.

Many of the foremost marine engineers in the country are greatly against the system now so generally adopted by the Admiralty of making sets of engines for different ships interchangeable. Whatever its military advantages may be, there can be no doubt that it does not make for thoroughly careful design on the part of one firm when it knows that all its drawings will be given to another firm to work to, however amicably they may arrange the interchange. That basic plans should be got out by one company and adhered to "by command" can only restrict progressive design, and we are not surprised, therefore, when we find a fault made in one design carefully duplicated in several others. Unnecessary length between bearings, excessive scantlings in cylinder-end pedestals, thrust blocks or bearing covers, should all be subjected to far keener criticism from the manufacturers' point of view than is at present encouraged by the existing system.

Less remains to be done in the way of reducing the weight of rotors in existing designs than in the case of cylinders. The essential drum and end spindles will remain, but some alteration will probably take place in the form of wheel adopted for connecting the two. A cast-steel hollow-spoked spindle has up till recently been adopted, this form having been calculated as being best adapted to resist compression and twisting on a given weight of material. The recent trouble, however, with the cast-steel rotor wheels of H. M. S. *Superb* has resulted in an order being placed for this item in forged steel, though with practically no difference to the weight.

Although somewhat outside the weight of turbines proper, the condensing plant forms no inconsiderable portion of the total weight. The design of marine condensers at present reflects little credit on the engineers responsible, some of the condensers in the destroyers being nothing beyond circular or oval boxes of tubes. Less water and pumping power and much smaller condensers will result when the—somewhat obvious—fact is grasped that an efficient square foot is more use than many square feet of not only useless but harmful surface. A great deal remains to be done in leading the steam properly among the tubes, and steam speeds and passages need much revision. When this is done, and the surface in a condenser made as equal in efficiency as possible all over, the size and weight of condensing plants will also be much reduced. The arrangement of exhaust pipes to the condenser in most marine installations is not one that is well adapted for distributing the steam properly over the tubes. Adequate area is seldom or never allowed through the tube rows nearest the inlet, and much greater condensing efficiency must obviously result from a more equable distribution of work throughout the condenser.

The size of steam piping and valves merits attention with turbine machinery, the permissible speeds of steam and exhaust being much higher, thereby admitting of reduced pipe diameters. The fall of pressure between the throttle valve and turbine is constant, whereas in a reciprocating engine the closing of the slide valve induced a pulsating effect that demanded a slow speed of delivery. A very slight pressure drop is sufficient to cause a steam speed far in excess of that academically laid down in text books for the diameter of steam pipes.

Many other points might be cited, but in dealing with the above we have been careful to bear in mind specific cases of exaggerated dimensions or unsuitable proportions in recent practice. What we now desire to call attention to has reference to future practice more particularly, though the matter has for long enough been fully realized in certain specialist circles.

From the point of view of weight, cost and efficiency, the determination of the best dimensions of the marine turbine depends on the accuracy with which it is proportioned to the work it has to perform, and on the correctness with which the balance between the turbine and the propeller is struck. We have numerous cases in which the propeller is too large, or rather larger than is advisable for the turbine, but far more frequently do we find an unnecessarily powerful turbine. Setting aside for the moment the determination of relative proportion, the first step must at least be to determine propeller dimensions for any given power, speed and number of screws. A simple calculation shows the difference that may be made by the adoption of very slightly different ratios and pressures in the same type of design. Take a Channel steamer of 24 knots speed and 12,000 shaft horsepower. The propeller efficiency is known to be about 50 per cent. There will be three shafts.

Effective horsepower $= 12{,}000 \times .5 = 6{,}000$,

Effective thrust $= \dfrac{6{,}000 \times 326}{24 \times .95}$ where .95 is the wake factor $= 85{,}700$ pounds.

Some designers will allow a thrust pressure per square inch projecting area of 11 pounds in association with a projected surface ratio of 0.45, while others would go to 11.5 and a surface ratio of 0.5. The resulting diameters would be 7 feet $1\frac{1}{2}$ inches and 6 feet $4\frac{1}{2}$ inches respectively, and, with a pitch ratio of 0.95 and 20 per cent. slips in each case, the revolutions would be about 450 and 500 per minute respectively. The greatest care must be taken to use pressures and proportions that admit of efficient high speeds, as in this case one turbine set will weigh approximately 15 to 20 per cent. more than the other.

Equally important is the accurate determination of effective horsepower necessary to propel a given ship at a given speed. There are innumerable instances of this being exaggerated in the design, and the vessel attaining an unlooked for speed. One of the latest cases is undoubtedly that of the United

States cruiser *Chester*, which was designed for 24 knots and obtained 26.52, an increase in speed corresponding to about 33 per cent. in power. Another case is that of the *Tartar*, which was designed for about 15,000 shaft horsepower and gave 20,000. To some extent the boilers may have been too generously proportioned, but in each case the turbine was either able to pass over 30 per cent. more steam than it was designed for, or else, for its designed power, it was unnecessarily large. In the above example, taking 11.0 pounds and 0.45 surface ratio as a basis, should one designer estimate the E.H.P. required at 5,500 and another at 6,500, the difference in speed of rotation would be 470 and 430 revolutions respectively.

This is a subject upon which much more might be said. The accurate determination of horsepower required to propel a given ship is of the greatest importance, affecting as it does the entire vessel. More especially does this apply to turbine work, where the area of the propeller is such an essential feature in the design. Recourse should be had, whenever possible, to an experimental model tank. As we have tried to show, the matter does not end here; careful attention to the details of a design should not be relaxed for a single moment.—" The Engineer."

NAVAL ARMAMENTS.

Translated by CAPTAIN S. G. SHARTLE, C. A. C.

On fleet plans and shipbuilding activity the "Taschenbuch der Kriegsflotten," 1908, page 381, has the following to say:

The English navy has inaugurated a new era in warship building. By the creation of their so-called *Dreadnought*, they have forced other sea powers to provide similar ships of at least 18,000 tons, with correspondingly powerful guns. European, as well as other nations, have for some time shown by their naval armaments their appreciation of the political

and economical importance of sea power. We therefore see these new giants of the sea building everywhere. France, Russia, Germany, the United States, Japan and even the smaller countries, as those of South America, are constructing them.

Differences of opinion exist only in respect to armament, whether they shall carry, in addition to the light anti-torpedo-boat guns, only the heaviest caliber, or also medium, or two heavier calibers.

Since against such a modern Colossus the former battleships (or armored cruisers)—taken ship against ship—have no prospect of success, a return to smaller battleships is not to be expected.

Therefore the value of the old battleships and also those of today's fleet is declining—corresponding to the increase in the number of *Dreadnoughts*—and the strength of a fleet will be measured in a short time chiefly by the number of the new battleships it includes.

There results a new starting point for the naval equipment of all sea powers.

Those that decidedly surpass in the building of modern ships will be in position to overtake the tardy navies of previous greater strength.

Thus the course of development that the armored ship and its armament has taken, thanks to the changes made by England, offers to the younger and smaller navy proportionately more favorable opportunities for developing than to the older and larger fleet, which has so much more naval material and yet must completely supply itself with the new.

Germany proposes to adapt her building program to the new conditions, as outlined above. The Navy Program of 1908, it is stated on page 382 of the "Taschenbuch," requires the changing of paragraph 2 of the law of June 14, 1900, regulating the building and rehabilitation of the fleet. This paragraph reads :

"Exclusive of ships damaged, battleships are to be replaced after 25 years, cruisers after 20 years."

The new wording is to be:

"Exclusive of ships damaged, *battleships and cruisers are to be replaced after 20 years.*"

The following parts of the paragraph are not changed:

"The spaces of time run from the year of the granting of the first appropriations for the ship to be replaced to the granting of the first appropriations for the replacing ship."

"For the period from 1908 to 1917 the construction for substitution is regulated according to program B."

The above change necessitates a rearrangement of this program. The old and new are here given together (see page 383):

DISTRIBUTION OF THE SUBSTITUTION CONSTRUCTION FOR 1908 TO 1917, INCLUSIVE.

Program B (old).				Program B (new).			
Year of substitution.	Battleships.	Large cruisers.	Small cruisers.	Year of substitution.	Battleships.	Large cruisers.	Small cruisers.
1908	2	...	2	1908	3	...	2
1909	2	...	2	1909	3	...	2
1910	1	1	2	1910	3	...	2
1911	1	1	2	1911	2	...	2
1912	1	1	2	1912	1	1	2
1913	1	1	2	1913	1	1	2
1914	1	1	2	1914	1	1	2
1915	1	1	2	1915	1	1	2
1916	1	1	2	1916	1	1	2
1917	2	...	1	1917	1	1	1
Total...............	13	7	19	Total...............	17	6	19

Other paragraphs of the law of June 14, 1900, which are not changed, will stand as follows:

I. SHIPS.

There shall be

1. *The battle fleet:*—2 fleet flagships, 4 squadrons, each of 8 battleships, 8 large and 24 small cruisers as scout ships.

2. *Foreign fleet:*—8 large cruisers and 10 small cruisers.

3. *Reserve material:*—4 battleships, 4 large cruisers, 4 small cruisers.

II. LENGTH OF LIFE.

(Quoted above concerning length of active life of battleships and cruisers.)

III. COMMISSIONING.

With respect to the commissioning of the battle fleets, the following principles hold: 1. The 1st and 2d squadrons form the active battle fleet; the 3d and 4th squadrons, the reserve battle fleet. 2. Of the active battle fleet, all are kept in commission; of the reserve battle fleet, one-half of the battleships and one-half of the cruisers are kept in commission. 3. For maneuvering, individual ships of the reserve out of commission are placed in commission temporarily.

According to the foregoing law, the German fleet is to include:

38 battleships.
20 large (armored) cruisers.
38 small (protected) cruisers.
144 torpedo boats.

The above tables refer to building to replace old ships. The following table gives the shipbuilding plan of Germany to 1917, including the increases; the latter are marked v:

Year of substitution.	Battle ships.	Large cruisers.	Small cruisers.	Torpedo-boat division.
1908	3	1 v	2	2
1909	3	1 v	2	2
1910	3	1 v	2	2
1911	2+1 v	1 v	2	2
1912	1	1	2	2
1913	1	1	2	2
1914	1	1	2	2
1915	1	1	2	2
1916	1	1	2	2
1917	1	1	1+1 v	2
Total	18	10	20	20

Great stress has heretofore been laid upon the fact that the English 30.5-cm., Mark X, L/45 gun is the most powerful used on shipboard. Its projectile weighs 385 kg., has an initial velocity of 884 m.s. and hence an energy of 15,360 m.t. A new type of this gun, L/50, Mark XI, is now under construction for the *St. Vincent* class of ships (three, of 20,900 tons displacement). This gun fires the same projectile as the Mark X, but with an initial velocity of 902 m.s., and therefore an energy of 16,000 m.t. But they are not satisfied even with this, for under "ships' guns of England" is specified as under construction a 13½-inch (34.3-cm.) gun, L/45, which is intended to impart to a projectile of 567 kg. an initial velocity of 860 m.s., an energy of 21,350 m.t.; that is, more than double the energy attained by the German 28-cm. gun, L/40. Whether this statement is correct appears questionable, for, although this gun is to be produced in England, it is intended for the Brazilian navy.

Even this gun, however, is surpassed by an 18-inch (45.7-cm.) gun, L/28, which imparts to a projectile of 907 kg. an initial velocity of 685 m.s.—that is, an energy of 21,738 m.t. This gun is made by the North American firm, the Bethlehem Steel Company, and has the short life of all long guns of large caliber. Certainly this firm has greatly exceeded the first caliber given (35.56 cm.).

While the English and North American factories seek to increase the ballistic performances of their guns by increasing the velocity or the weight of the projectile, the Krupp factory holds fast to the ballistic performances attained by it as long ago as 1901. These results placed them at the head, and were first surpassed by the two guns mentioned above. The Krupp firm set great store on the fact of attaining the same ballistic performance with a gun considerably smaller in weight, and this has been accomplished in an absolutely surprising manner by the new guns, model 1906. The heavy 30.5-cm. gun, L/50, designed for coast artillery, with a weight of 63,400 kg., performs work of 17,500 m.t.; the same work is accomblished by a Krupp gun of only 48,000 kg. The

heaviest gun of the German navy is the old 28-cm. gun, L/40, which weighs 44,000 kg. It possesses an energy of 6,740 m.t. Although the weight of the new gun is not 10 per cent. greater, the work performed by the new Krupp gun is almost 160 per cent. greater. We now get 365 m.kg. of energy for one kg. of weight; this is the highest efficiency that has been reached in artillery, and it is surpassed only by the guns 40 and 45 calibers long of the Krupp firm. The long Krupp rapid-fire guns, model 1906, of all calibers, show the same high efficiency.

It is worth mentioning that the firm of Vickers & Sons has decreased the initial velocity of their 15.2-cm. gun, L/50, from 1,030 to 972 m.s. So the highest initial velocity now is that of the projectile of the 20.3-cm. gun L, 51.6, of the same firm, namely, 1,006 m.s. (not 1,060, as given in the "Taschenbuch" for 1907, through a typographical error). Next stands the Krupp 10-cm. gun, L/50, with 1,000 m.s. initial velocity.

One may wonder whether the movement which England and North America have undertaken with respect to caliber will find imitation in other States. It may be remarked incidentally that the caliber of 18 inches (45.7 cm.) is the largest that has ever been undertaken in artillery, if one excepts the legendary guns, which are supposed to have been used soon after the invention of gunpowder, for example at the taking of Constantinople.—"Artilleristische Monatshefte," March, 1908.

COMMENTS ON ABOVE NOTES BY TRANSLATOR.

It is thought that a more complete comparison of high-power guns than the above may be of interest. To this end the table on page 750 has been prepared.

It will be seen by the table that so far as power, measured in muzzle energy, is concerned, these guns rank as follows:

U. S. Coast....................16-inch.
Bethlehem......................18-inch.
English........................13.5-inch.
Krupp..........................12-inch.
Schneider-Canet................12-inch.
Skoda-Werke....................12-inch.
Vickers-Maxim..................12-inch.
U. S. Coast....................14-inch.
English........................12-inch.
Sweden, Bofors.................12-inch.
England, Armstrong.............12-inch.
U. S. Coast....................12-inch.
U. S. Navy.....................12-inch.

State.	Caliber.	Length.	Initial velocity.	Weight of projectile.	Muzzle energy.	Weight of gun.
	Inches.		*f.s.*	*Pounds.*	*ft. tons.*	*Tons.*
U. S. Coast	12	L-45	2,500	1,046	45,375	56.6
U. S. Navy	12	L-45	2,700	869	43,960	50.0
England, Armstrong	12	L-45	2,900	850	49,540	58.0
England, Navy	12 M XI	L-50	2,960	847	51,630	66.0
England, Vickers' Sons & Maxim	12	L-46.5	3,000	850	53,016	57.7
Germany (Krupp), Navy Coast	12	L-50	3,250	981	56,450	47.7 52.6
French, Schneider Canet	12	L-50	3,120	827	55,646	57.5
Austria, Skoda Werke	12	L-50	3,150 2,790	772 992	53,794	60.3
Sweden, Bofors	12	L-50	3,075 2,715	772 981	50,138	49.2
England, Navy	13.5	L-45	2,820	1,247	68,746	86.0
U. S. Coast	14	L-35	2,150	1,650	52,940	49.5
U. S. Coast	16	L-40	2,345*	2,400	91,500	130.0
U. S., Bethlehem Steel Works	18	L-28	2,250	2,000	70,200	60.0

* On test firing.

As stated, the tendency, in the United States particularly, and in England in one case, is to gain power by increasing the caliber; in Germany and other countries the same end is attained by increasing the velocity. This question need not be gone into here, but the figures of the table stare one in the face. The artilleryman wants: first, a great number of hits in a short time, and, second, great striking energy, since the latter is entirely a waste without the former. Rapidity of hits means: first, flat trajectory, that is, high initial velocity; and, second, a light projectile and gun, the latter not being so important. Great energy means either high velocity or great mass. The latter alternately results in slow fire and less danger space. By the former, high velocity, the artilleryman increases his chances for hits and at the same time the energy. Surely, he wants high velocity, if it can be attained. But it is objected that high velocities wear out guns so rapidly that their efficiency is impaired and their objects, hits and energy, defeated. This is a problem for the gun maker and not for the artillery. Other countries have apparently solved it—the

13.5-inch gun of the English still has 2,800 f.s., and the Krupp 12-inch gun is put down at 3,250 f.s. This gun fires a projectile of 981 pounds and gives a muzzle energy of 56,450 foot-tons as against 52,940 foot-tons energy with a projectile of 1,650 pounds of our 14-inch gun. The English 12-inch gun, with a projectile of 847 and initial velocity of 2,960, falls little short of the 14-inch gun in energy, viz: 51,630 foot-tons. It must be admitted that the English and German guns come nearer the artilleryman's ideal of a high-power gun than does the 14-inch gun.

As to the technical efficiency (*verwertung*) of a gun, expressed in the ratio of work to weight, the coast artilleryman is not much concerned. A few tons more or less matter little in the handling on a stable platform. But even here the German gun is superior, the efficiency of the Krupp seacoast gun being 1,071 foot-tons of work to 1 ton of weight, and of the Krupp navy gun 1,183 to 1; while the efficiency of the 14-inch gun is 1,070 to 1. However, as said before, this is a question of more interest to the constructor than to the artilleryman.

As a matter of historical interest it may be well to correct the statement that the Bethlehem 18-inch gun is the "largest ever made, if the legendary guns of the time of the taking of Constantinople be excepted." As late as the 80's, the United States army and navy each had a few 20-inch smooth-bore guns, which were listed as available for service.

RECENT FRENCH TORPEDO-BOAT DESTROYERS.

The French navy will this year be augmented by a flotilla of twenty-one torpedo-boat destroyers. The first batch of these has recently been completed, and on their trials the vessels attained a mean maximum speed of 29½ knots, which may be considered as satisfactory, having regard to their tonnage. The accompanying Table I gives, under the heading *Sabretache*, the principal data concerning these boats, while under the heading *Mousquet* are given those of a type which

immediately preceded the *Sabretache* class, and under the heading *Chasseur* details of some later vessels which are at the present time under construction. For the purpose of comparison we also give in Table II some corresponding particulars regarding the British coastal destroyers, and the *Tartar*, as well as those concerning the German destroyer *G 137*. A comparison of the figures in these two tables is instructive, and emphasizes the contentions brought forward in the following criticisms, which are those of a Frenchman well versed in matters concerning not only the Navy of his own country, but also those of other powers. He contends that the vessels of the French navy which are called torpedo-boat destroyers, or to use the French term *contre-torpilleurs*, are destroyers in name only. They are, in fact, very similar to the British "coastal destroyers," which are now-a-days called first-class torpedo boats, but are much inferior both in

Table I.—DETAILS OF RECENT FRENCH DESTROYERS.

Nationality	France.	France	France.
Class type	*Mousquet.*	*Sabretache.**	*Chasseur.*
Displacement	302.76 tons	328.70 tons	447 tons
Length at the water load line	184 ft. 8 in.	190 ft. 4 in.	210 ft. 8 in.
Breadth at water line	19 ft. 8 in.	20 ft. 7 in.	22 ft
Draught (astern)	9 ft. 4 in.	9 ft. 9 in.	7 ft. 9 in.
Boilers	2 Normand or Du Temple	2 Normand	4 Normand
Engines	2 3-expansion; 3 cylinders	2 3-expansion; 3 cylinders	1 3-expansion 3 cylinders at center; 2 turbines at wings
Propellers	2	2	3
I. H. P. (expected)	6,300 to 7,200 on trials	6,800	7,200
Speed on trials (max)	28 (mean) 30.75	29.5, 30.7	28 knots
Bunker capacity	27 tons	30 tons	......
Radius of action at 10 knots (estimated)	2,300 miles	2,300 miles	2,300 miles
Radius of action at full speed	217 miles	217 miles	......
Armament	1 of 65 mm. 4 of 47 mm.	1 of 65 mm. 4 of 47 mm.	6 of 65 mm.
Torpedo tubes	2 of 450 mm (18-in.)	2 of 450 mm. (18-in.)	3 of 450 mm. (18-in.)
Crew	4 officers, 56 men	4 officers, 58 men	......

* It is worthy of note that this latest type has as protection a deck plating of nickel-steel above the boiler and engine room—this nickel plating is 20 mm. thick (¾-in.), and that the *Chasseur* has similar protection on deck—20 mm. nickel-steel.

These last destroyers are six in number. Three of them will be fitted with a central triple-expansion, three cylinders, main engine and side twin-screw turbine engines. The turbines are of different types—one is of Parsons type, one of the Rateau type and one of the Breguet type. The other destroyers will be fitted only with two main engines of the usual type. It is said that liquid fuel will be used on certain of them (*Chasseur, Voltigeur, Tirailleur* fitted with turbines).

Mortier, Fleuret, Coutelas, Stylet, Troublon, Cognee, Carquois, Trident, Pierrier, Hache, Massue, Glaive, Poignard (which have been built in the dock yards), *Branlebas, Etendart, Fannion, Sape, Fanfare, Gabion, Cognee, Oriflamme* belong to the *Sabretache* type. Those of the *Spahi* type include *Voltigeur, Hussard, Tirailleur, Carbinier, Chasseur.*

Table II.—DETAILS OF RECENT BRITISH AND GERMAN DESTROYERS.

Nationality	England.	England.	Germany.
Class type	Coastal destroyer	*Tartar*	*G 137*
Displacement	215 tons	900 tons	572 tons
Length	166 ft. 6 in.	272 ft.	244 ft. 9 in.
Breadth	17 ft. 6 in.	26 ft.	23 ft. 9 in.
Draught (astern)	5.8 ft.	9 ft.	8 ft. 9 in.
Boilers	2 Thornycroft	4 Thornycroft	4 Schultz
Engines	3 Parsons turbines	3 Parsons turbines	3 Parsons turbines
Propellers	3	3	3
I. H. P.	3,750	14,500	10,000
Max'm speed on trials.	27.52	35.672 (mean of 6 runs)	33.10
Bunker capacity	20 tons	74 tons of oil	......
Radius of action	1,200 miles at 13 knots	1,700 miles at 13 knots	......
Armament	2 12-pounders	2 4-in. guns in some of the class	1 of 88 mm., 4 of 52 mm. 2 machine guns
Torpedo tubes	3 18-in.	3 18-in.	3 18-in.
Crew	35	68	......

* The coastal destroyer is now classed in our Navy as a first-class torpedo boat.

armament and speed to the British and German destroyers which were built at the same time. They could be regarded, continues the critic we are quoting, as torpedo-boat destroyers only in French naval maneuvers. The type of modern destroyer of the great maritime nations against which these vessels would have to pit themselves range up to nearly 900 tons displacement, and it is certain that in an engagement the French craft would be little, if any, better than torpedo boats pure and simple.

From the foregoing it is clear, he points out, that these so-called destroyers would have no opportunity of displaying their qualities as destroyers of torpedo boats. Fighting, as they would have to, did they engage with either the British or German flotillas, they would meet with certain destruction, since they would have to deal with enemies which are individually stronger, and, taken collectively in squadrons, more numerous.

Further than this, it is pointed out that the fact that the French destroyers are so different from their counterparts in other navies arises from the fact that in France there is an entirely wrong conception as to the duty which this type of vessel is called upon to perform. So far from having to contend with boats smaller than themselves, they will be opposed to vessels which are superior in every way, and it is added that the function which they are capable to some extent of performing is that of protecting a squadron of larger vessels

from attack—though when due consideration is made of all the factors, they are really not even powerful enough for that duty.

These strictures, coming as they do from a Frenchman, and one who is acquainted to a very considerable degree with naval matters, are undoubtedly severe, but it cannot be denied that the authority we are quoting makes out a very good case against the latest additions to the French flotilla of destroyers.

The following are among his reasons for his statements:

In the first place, the speed of this type of boat is not sufficient. A mean speed of from 32 to 33 knots on service ought, he considers, to be the minimum. Moreover, the weight and the space set aside for machinery and boilers ought to be increased, so as to avoid having delicate boats, whose speed has to be reduced considerably as soon as a bit of sea is met with. At all events, oil fuel and steam turbines should be employed, as these alone will give for a minimum of weight the speed required and the necessary radius of action. The strength of the decks should also be greater than it is, so that under no circumstances can any boat be injured when making use of her armament. Even under the most favorable circumstances it is necessary, in order that a torpedo may be certain of reaching its mark, that it should be fired as near as possible to that mark, so that the causes of error arising from distance, and from the speed and direction of the vessel aimed at, may be reduced to a minimum. To this end it is necessary that the attacking boat should have its stability, speed and facility of maneuvering most perfectly developed, and it is urged that it is impossible to have all these qualities condensed into a hull of only 328 tons' displacement. At least 600 tons would be required.

With such a displacement a type of destroyer might be developed which could maintain a speed of from 32 to 33 knots on service; could carry an armament of three torpedo tubes, three 100-mm. and six 65-mm. guns. Such a vessel could render all the services required of modern vessels of

this type, that is to say, it would be capable of playing either an offensive or a defensive part, and could protect the coasts or accompany fleets.

Our critic considers that the best policy which the Conseil Supérieur of the French navy could pursue is that carried out by the German authorities, for it could not hope to equal England, against which it would be necessary to bring a fleet capable of taking the offensive, whereas in recent years the French fleet has declared itself to be purely for defensive purposes.

At this point he draws attention to several anomalies which exist in the French navy. Until quite recently the chief destroyers of a group of torpedo craft were painted white, while their attendant vessels were painted black. This he ironically presumes was in order to render it more easy for an enemy to discover the presence of a flotilla which was to attack it! Lately, however, the chief vessel of a group has been painted —to use the French expression—*en toile mouillee*, a kind of khaki. It would have been much more simple, it is urged, to have all the hulls painted black or some other neutral tint.

It is also remarked what little progress has been made in the French marine in the use of oil fuel. It is not as though experiments in this direction in France were only a thing of yesterday. The first trial of liquid fuel in that country was made, our informant believes, on the yacht *Aigle*, which belonged to Napoleon III. The matter was then dropped, taken up again, again dropped, and so on. "It is true," he continues, "that use is made of a combination of liquid and solid fuel, but France has not achieved the splendid results obtained in the British navy, of which the scientific spirit, the desire to excel, and the methods of research are admirable, and are the source of its perfection and of the superior work done by this fleet, which is followed in the line of progress by that of Germany. The latter country, although it has only lately started on the conquest of the world, takes a rank

which is continually becoming more important, and the importance of which must go on increasing."

The *contre-torpilleur Sabretache*, has the following characteristics:

Length on the water line	58 m., say 190 ft. 2¼ in.
Beam	6.28 m., say 20 ft. 7 in.
Maximum draught	2.96 m., say 9 ft. 8 in.
Corresponding displacement	328.7 tons.
Indicated H.P	6,800.
Number of boilers	2 (Normand).
Working pressure	265 lbs.
Grate area	162 sq. ft.
Heating surface	7,500 sq. ft.
Number of engines	Two. Triple-expansion, three cylinders, 19 in., 31 in. and 45 in.
Stroke of pistons	23 in.
Revolutions per minute	310.
Speed to be realized during six hours	27½ knots.
Coal consumption required per sq. meter of grate area in full-power trial	400 kilos, 37 lbs. per sq. ft.

It is remarked that although this type of destroyer, or, more correctly, seagoing torpedo boat, has a slightly greater displacement than its predecessors, its quarters are less comfortable, which is certainly not an advantage, because it is impossible to expect the same work from a tired crew, which can only with difficulty obtain repose, as from a crew which can sleep in greater comfort. There are other points in the design which are far from being in the direction of progress.

The complement of this type of boat is 4 officers and 58 men. The bunker capacity is 30 tons of coal, which gives, according to our informant, a theoretical radius of action of 2,300 miles at 10 knots. The armament is very weak. There is one 65-mm.—2.56-inch—gun in the bows, and six 47-mm.—1.85-inch—guns on the broadside. There are two torpedo tubes, one amidships and one astern, for 450-mm.—18-inch—torpedoes of the latest type.

The *Sabretache* was built in the yard of MM. de la Brosse et Fouche, of Nantes, who have constructed not only the hull, but also the engines and boilers. She was launched in a prac-

tically complete state, with machinery on board. She began her builders' trials only a few days after she was launched.—"The Marine Review."

MANGANESE-BRONZE.

By C. R. Spare.

Paper read before the American Society for Testing Materials, at convention, June 23-27, 1908.

It is not the intention of this paper to review the history of the development of the various manganese-bronzes up to the present day, but to outline briefly the vastly extended uses to which these valuable alloys have been applied in recent years by the various industries, and, more especially, to point out the methods of testing employed and the physical results obtained.

The best present-day alloys of manganese-bronze are the results of years of scientific research by several of the largest manufacturing concerns in the world, who maintain chemical and physical testing laboratories in connection with their brass foundries. Of all the metal industries, brass founding is almost the last to pass from the empirical and rule-of-thumb to a scientific matallurgical basis. In fact the majority of the brass and bronze manufacturers today have never used chemical analysis or a testing machine, and, therefore, have only a general idea of the composition and physical properties of their products. This is the result of natural conditions, which years ago did not impose severe requirements on brass and bronze.

Today conditions have changed, or are changing, and engineers have multiplied powers and manipulated pressures beyond all former figures. Machinery is more powerful, more complicated and more severely tested than ever before, and while steel and other industries have made great advances and kept apace of requirements, the same ratio of improvement has not been maintained in the copper and brass metals,

excepting in the case of the high tensile-strength manganese-bronzes.

There are several brands of manganese-bronze on the market, each with its own characteristics, which are determined by the chemical composition and the process of manufacture. While upon analysis some of these bronzes do not reveal striking differences in composition, yet these alloys are susceptible of wide variations in physical properties by slight changes in composition, difference in quality of raw materials and methods of melting and mixing.

Certain impurities affect very injuriously the strength and ductility of manganese-bronze, causing brittleness and crystalline texture. It is not within the compass of this paper to discuss these differences, but they become very evident in the testing machine.

APPLICATIONS.

Manganese-bronze first found its important practical application in the manufacture of propeller wheels for ships. Now, cast iron and cast steel have been almost universally displaced by it, not only for all naval vessels, but the merchant ships of the world have adopted it as standard practice. Marine engines have been increased to such vast powers, especially during the past ten years and since the advent of the steam turbine, that 20,000, then 40,000, and now 70,000 I.H.P. are transmitted through manganese-bronze propeller wheels. In some ships the speed runs upwards of 300 revolutions per minute.

PHYSICAL PROPERTIES.

There is no metal of equal strength and toughness which will produce such sound, smooth and intricate castings, true to the form of the pattern. These qualities permit of the maximum fineness of section of the propeller blade, and at the surface speeds of thousands of feet per minute the surface friction is reduced to a minimum.

This bronze is practically incorrodible in sea and alkali

waters. Likewise dilute acids and acid mine water are withstood very successfully. Long-time tests have been made with the various acids and mine waters. Cast blocks of manganese-bronze immersed in the most acid mine water in Pennsylvania, containing about 300 grains sulphuric acid per gallon, for one year, showed no material corrosion, and a test piece cut from this metal showed no diminution in tensile strength over a duplicate specimen previously tested.

TESTING.

Test pieces cut from cast propellers should show an average ultimate tensile strength of 70,000 pounds per square inch, elastic limit of about 35,000 pounds, or one-half the ultimate; elongation in 2 inches, 25 per cent., and reduction of area, 25 per cent. The reduction of area follows the elongation closely in cast manganese-bronze.

These figures can be varied to suit requirements. A soft manganese-bronze having an ultimate strength of 60,000 pounds per square inch and 40 per cent. or 50 per cent. elongation in 2 inches is the lower limit, while an exceedingly hard manganese-bronze can be made to test over 90,000 pounds per square inch, with even as much as 30 per cent. elongation.

The methods of testing manganese-bronze physically do not differ materially from the standard methods for steel. Test pieces, according to the U. S. Government standard sizes, .505 inch, .798 inch or 1 inch diameter, are machined 2 inches between punch marks, and threaded. In the case of castings there is not a sharply defined elastic limit, and the yield point cannot be determined by the drop of the beam. A multiplying divider (such as devised by J. A. Capp), or a standard extensometer will establish quite closely the point at which an appreciable change in the rate of stretch takes place. In the case of rolled or forged manganese-bronze the yield point is more closely defined and the elastic curve is frequently sharp enough to detect the drop of the beam or halt of the gauge wheel.

In compression, cast manganese-bronze, if properly made, shows an average elastic limit of 35,000 to 40,000 pounds per square inch, and a maximum crushing load of 90,000 to 100,000 pounds per square inch. Rolled or forged manganese-bronze tests 50,000 to 60,000 pounds elastic limit, and as high as 130,000 to 150,000 pounds maximum crushing load.

ROLLING AND FORGING.

Manganese-bronze can be rolled or forged readily at a red heat with the production of an exceedingly tough, dense and close-grained metal. Microscopic examination of cast manganese-bronze after polishing and etching reveals a very homogeneous and uniformly grained metal, but after rolling or forging to a sufficient reduction the structure is reduced to from $\frac{1}{80}$ to $\frac{1}{50}$.

Rolling and forging raise the proportional elastic limit to from 45,000 to 75,000 pounds per square inch, depending upon the finishing temperature and the amount of work done on the metal. Likewise the ductility and toughness are increased without, however, a corresponding increase in ultimate strength.

Forged and rolled rods find a wide application as piston rods, shafts, axles, and for all purposes where a metal of equal strength and toughness to carbon-steel is desired, and which will not rust or corrode in the atmosphere, mine or sea water.

An especially soft and tough metal is made to resist vibratory and sudden stresses and shocks. It is used under very severe conditions in modern naval ordnance. It also is finding application in staybolts for locomotives. This bronze tests 40 to 50 per cent. elongation with about 60 per cent. reduction of area.

Thus only a few of the better known applications of manganese-bronze have been pointed out.

The electrical industry is calling for it for turbo-generator sets which are run at speeds up to 4,000 revolutions per min-

ute, and the blades of the steam turbine are satisfactorily made of extruded manganese-bronze shapes. In this case the erosive action of high-pressure steam is a severe condition under which most metals fail.

APPLICATIONS.

The infant industry of this country, which has grown to such lusty proportions, the automobile, has set a very high standard for materials, which must stand up under its peculiarly hard service conditions. Automobiles with gasoline motors of 60 and even as high as 130 H.P., at speed of 1,000 to 1,500 revolutions per minute and running over all kinds of roadbeads at 60 and 100 miles an hour, have stimulated the improvement of the materials entering into the construction more, perhaps, than any other modern machine. The nickel-chrome and other high-grade steels have produced results never heard of before, and cast iron has been wonderfully improved by the requirements of automobile cylinders. Likewise manganese-bronze, formerly used almost exclusively for warships, has been adapted to produce forgings and castings which will not crystallize or fail under similarly severe conditions.

As stated at the outset, it was not the purpose of this paper to explain the theory or history of the deoxidation of copper by means of manganese, but it has been attempted to outline the growing application of these alloys and to present a general idea of the physical tests obtained by several government and private testing laboratories, with the hope that the engineers of this country will become more interested and better acquainted with these alloys.—"The Metal Industry."

THE LUBRICATION OF MARINE-ENGINE CYLINDERS.

Regarding the lubrication of marine-engine cylinders, my experience is that a vertical engine having a piston valve on the high-pressure cylinder will, and does, run as well without internal lubrication as with it. I have operated engines that had a piston valve on the high-pressure cylinder, or on the

high-pressure and intermediate-pressure cylinders, both with and without internal lubrication, and could see no difference, except that in case of the engine using no internal lubrication the piston rods had to be watched a little more closely to prevent heating.

As to using graphite for the purpose, it is sometimes added to the cylinder oil in the swabbing bucket, but I have never seen it introduced into the steam, although I do not see why it would not prove effective.

There is one thing in modern marine engines which I think could be adapted to stationary engines with considerable advantage, and that is the use of liners in the valve chests and cylinders.

The cylinders are cast of ordinary gray iron and fitted with liners of hard, close-grained cast iron. When the liner will stand no more re-boring it may be removed and a new one substituted.

The liner is flanged at the bottom and secured by bolts. It is free to move at the upper end and is made steamtight at that end by a copper wire calked into an under-cut groove between the liner and cylinder, or by a gland and packing space. Of course, it adds somewhat to the initial cost of the cylinder, but makes the cylinder everlasting, and it is much cheaper to renew than a new cylinder would be, while it gives a good, hard-wearing surface for the piston rings to bear on. Then, it may be removed after one light re-boring and the new liner put in, thus obviating the expense of a new piston. The liner is usually given a bearing at the top, at one or two points on the way down and at the bottom, and the spaces around it may be used as a steam jacket or not, as desired.

Possibly the hard, close-grained wearing surfaces may have something to do with the polish found in opening the cylinders. I have been with engines which had no means of putting oil into the cylinders except through the indicator pipes, which was necessary in the low-pressure cylinder upon starting up.—A. T. Rowe, in "Power and the Engine."

OILING ARRANGEMENTS FOR STEAM TURBINES.

The prime importance of getting a perfect oiling system for any type of moving machinery is, of course, too obvious to need demonstration to any practical engineer, but with the exceedingly high rotating speeds of the types of steam turbines in use in this country, the oiling system is even more important than in the case of reciprocating plant, inasmuch as in the case of reciprocating engines it would be most unlikely that more than one bearing at a time would get warm, whether hand or automatic lubrication were adopted. A trouble of this sort, says the "Electrical Review," would probably involve the shutting down of that particular engine until the bearing had been examined, cleaned up, and put into working order again, but otherwise there is no probability of further damage.

The conditions attending the oiling arrangements of the turbine, however, are considerably different. The efficiency of the steam turbine depends very largely on the exceedingly small clearance between the rotor and the casing of the turbine, and should there be any displacement of the rotor with respect to the casing, the turbine blading would be entirely stripped, involving the destruction of the turbine as an efficient factor in the station for the few weeks necessary for reblading. Such a displacement could be very easily caused by the melting out of the white metal in the bearing at either end of the turbine shaft; the extreme importance, therefore, of watching this point cannot be overestimated.

There are two usual methods of lubrication favored by the various turbine builders in this country and America, named respectively the central system and the single-unit system. In the case of the central system a large tank is placed at the highest point of the building, which tank is kept full of oil. Pipework is arranged from the tank to the engine room, through which the oil flows by gravitation to the bearings of the turbines. By means of a parallel system any number of turbines can be supplied from the same oil tank up to its

limit in capacity. In leaving the bearings of the turbines the oil flows into a filter, and after passing through this it enters a series of two or three settling tanks, flowing from one to the other over weirs. From the last tank it is drawn off by means of a pump, and forced up to the supply tank again; and usually on its way up it is passed through cooling tanks through which water is continually circulating, thereby reducing the temperature of the oil almost to the atmospheric temperature.

The chief objection to this system is the danger of a total shut down of the oil plant owing to the giving way of a joint or pipe between the supply tank and the turbine bearings. Moreover, the first cost is particularly heavy, owing the fact that separate steam or electrically-driven pumps are required to keep up the circulation of the oil, and the tanks and pipework have to be of considerable capacity in order to meet all reasonable demands of probable extensions. The quantity of oil required at the first is also very great, sometimes running into thousands of gallons; and should anything occur to spoil the oil, either by an admixture of water or undue heating, the whole batch of oil is spoilt. As a matter of fact, however, the plant appears to work satisfactorily in places where it has been adopted, although the risk taken is probably too great to compensate for any advantage it may have.

The alternative system, in which each turbine has its own oil supply and pump, is probably the ideal one, as it reduces the risk of a total shut-down of the plant to a minimum. The bearings of each turbine are in this system water-jacketed, the water being supplied by one pump operating on any number of turbines required. Moreover, it has the advantage of low first cost, it confines the risk of spoiling oil to each particular turbine; and the system is under the more direct supervision of the engineer in the engine room. Most of the first-class turbine builders at present adopt this method. It is a logical expansion of the principle which has gradually found its way to the front with central-station design for the supply of power of any magnitude—that of the complete unit

system, whereby each piece of plant, from the boiler to the switchboard, is, so far as possible, self-contained, and works independently of other similar sets in the station.—"The Steamship."

PROGRESS OF WARSHIPS AND MACHINERY UNDER CONSTRUCTION IN ENGLAND.

As a leading London daily newspaper in one of its issues during the past month gave its readers what may justly be cited as a sensational description of a monster battleship to be laid down in Portsmouth Dockyard, on the slip to be shortly vacated by the battleship *St. Vincent*, we deem it advisable to assure our readers that no such naval construction has been contemplated by our Admiralty authorities; the detailed description of the imaginary "World's Largest Battleship" being nothing but pure supposition on the part of the writer; seeing that it is stated that she is to be some 3,000 tons heavier than the *Dreadnought*, and is moreover to be propelled by "gas" engines, a type that is so far only in the experimental stage.

That a new battleship will be laid down in Portsmouth Dockyard as soon as the *St. Vincent* takes the water is already known; but no particulars as to her dimensions, engine power, armament or speed are yet known, with this exception, that the vessel is to be an improvement on the *St. Vincent*.

With the foregoing intimation, and giving as heretofore priority of place in our record to the actual work completed and in progress in the Royal Dockyards, we first note that, since the date of the issue of "The Engineer" of January 10th last, such satisfactory progress has been made with the battleship *Bellerophon*, built at Portsmouth, that she gives promise of being ready for commission, complete in all respects—although no "overtime" has been worked upon her—within the two years allowed for her construction.

The unarmored cruiser *Boadicea* being built at Pembroke

Dockyard, and noticed in our record of January 10th last as progressing very satisfactorily in her construction, was successfully launched on the 14th of last May. This vessel is an improved and enlarged scout, being 385 feet long, with a displacement of 3,300 tons, and having at her load-water draught a bunker capacity of 350 tons. She will carry 100 tons of oil fuel. Her turbines, of 18,000 indicated horsepower, drive four propeller shafts, each fitted with a three-bladed screw propeller, cast in one piece with the boss. At full power her turbines are expected to make 500 revolutions a minute, and to propel the ship at 25 knots. Steam is supplied by twelve Yarrow boilers, worked at a pressure of 235 pounds per square inch, reduced at the engines to 170 pounds per square inch, the shipment of which on board was completed in three days—a record piece of work, reflecting great credit on all concerned, as the ship had first to be removed from her mooring to get her into a suitable position under the sheer legs. The *Boadicea* is the first ship built at Pembroke to be fitted with turbine machinery.

The keel plate of a new cruiser of the *Boadicea* class was laid down in a formal way at Pembroke Dockyard on the 15th of June, the laying down consisting in the plates being drawn into position on the blocks by an electric motor, and the first rivet driven into them by a pneumatic arrangement improvised for the purpose. Originally intended as a replica of her sister, the *Boadicea*, she is to have an additional displacement of 50 tons, but is to be of the same draught. The new ship will be 385 feet long between perpendiculars, have an extreme breadth of 42 feet, a displacement of 3,350 tons, and a mean water draught of 13 feet 6 inches, at which her turbine engines of 19,000 horsepower are expected to give her a maximum speed of 25 knots an hour. Her coal and oil-fuel stowage will be 450 tons.

The testing of the condensers, steam pipes and other small details of the armored cruiser *Defence*, built at Pembroke Dockyard, having been dealt with early in the past half year, the preliminary basin trials of her propelling engines have

been made, and were highly satisfactory, both engines having first worked together at a quarter speed, and then separately at half speed.

The battleship *St. Vincent*, the keel plates of which were laid in the last week of December, 1907, at Portsmouth, will at the date of her launch, on the 10th of September next, have been under construction but eight months and a-half. She is of the improved *Dreadnought* type, but has a displacement of 19,250 tons, or 1,350 tons more than the type ship. She is 500 feet long, with a beam of 54 feet and a mean water draught of only 27 feet. Her propelling engines, of 24,500 indicated horsepower, which are to be turbines, are designed to give her a speed of 21 knots under natural draught, steam being supplied by boilers of the Babcock & Wilcox type.

The propelling machinery of the *St. Vincent* is being made by Scott's Shipbuilding and Engineering Company, of Greenock, and rapid progress has been made with it during the past six months. The boring-out operations in connection with the propeller shafting is also proceeding apace at the ship. The work on the steam generators is also in a very forward state. In accordance with the latest Admiralty practice, these are adapted for burning oil fuel in conjunction with coal.

With the *St. Vincent* afloat, and completed, there will then be four ships in active service in our Navy that embody in their design and construction the *Dreadnought* principle; not taking into account several others of the same type being built or not yet completed for sea. The *St. Vincent's* building progress has been extremely satisfactory, as no "overtime" has been worked on her.

The progress of the battleship *Collingwood* at Devonport Dockyard, which was commenced on February 3, a little over a month later than that on the *St. Vincent*, has been very satisfactory. Up to February 8, 700 tons of material had been worked into her hull; by April 25, 2,500 tons; by May 7, 2,900 tons; and in the four working months after the ship was laid down about 3,300 tons. Such work reflects great credit on all employed on her, as the building "staff"

was smaller than usual on a similar sized vessel, and the "slip" not provided with such modern appliances as to enable work to be carried on more expeditiously and economically when on it than when afloat. The ceremony of laying the *Collingwood's* keel plate, which was in two portions, consisted in first riveting the two parts together and then transporting them to their proper position on the blocks. The ship is the sixth battleship of the *Dreadnought* type, and represents the latest ideas in big warship design.

The keel plate of a new armored cruiser of the *Boadicea* class, to be named the *Caractacus*, was formally laid on the building slip at Pembroke Dockyard on the 5th of June. She will be 385 feet long, 42 feet beam, and have a displacement of 3,350 tons, her mean water draught when loaded being 13 feet 6 inches. She will be propelled by turbine engines of 19,000 indicated horsepower to give her a speed of 25 knots, and will be armed like the *Boadicea*.

The ships in the "completing" stage in the Royal Dockyards are the battleship *Bellerophon*, at Portsmouth; the armored and unarmored cruisers *Defence* and *Boadicea*, at Pembroke; and the cruiser *Shannon*, at Chatham; the last vessel will shortly be ready for commission.

Turning, now, to the progress made in the past six months in warship and machinery construction in the private shipyards and engine works engaged in these industries in England, we find that during that interval, owing to the recent strike of shipyard workers in the Tyne district, a steady progress of warship construction, at the works of Sir W. G. Armstrong, Whitworth & Co., at Elswick, has not been maintained. Considerable progress has, however, been made in the work on the armored cruiser *Invincible*. The main armament of the ship is well advanced; the propelling and auxiliary machinery are practically complete, and the usual tests at the moorings have been carried out. The machinery trials are expected to take place shortly. The work on the battleship *Superb* is approaching completion, the fitting of the propelling machinery is in an advanced state, but its further

progress is retarded by the engineers' strike. The Brazilian battleship *Minas Geras* is to be launched in September, the work on board to that end rapidly approaching completion, the boring operations at the stern being finished, and the propeller shafts and propellers fitted in place. The progress of the fast scouts, *Bahia* and *Rio Grande do Sol*, for the Brazilian navy, has been somewhat delayed, but the framing and plating of the hulls are being pressed forward, so that a considerable advance may be looked for during the next six months. Since our last report on work at the Elswick shipyard, the Argentine river gunboat *Parana* has been successfully launched, and the work on board is well forward, machinery, armament and general fittings being well in hand. The sister ship *Rosario*, still under construction, is well advanced, and her launch may be looked for early this month.

Owing the strike of shipyard workers, there is very little to report in the way of warship work effected at Messrs. Hawthorne, Leslie & Co.'s establishments at St. Peter's, or Hebburn, during the past six months. The machinery, &c., of the battleship *Agamemnon*, constructed at St. Peter's, having been previously fitted on board and the sea and other trials successfully carried through, the vessel has been completed and handed over to the Admiralty, and is now commissioned. The strike prevailing in both the engine works and shipyards has delayed the completion of the 33-knot torpedo-boat destroyer *Ghurka*—whose successful trials were recorded in our last report—and she is still in the hands of her builders ready to be opened out for examination before Admiralty acceptance.

The *Afridi*, a similar vessel to the *Ghurka*, but built at Elswick shipyard, fitted with turbine engines by the Parsons Company, and boilers made at St. Peter's—a duplicate of those in the *Ghurka*—has also been laid up owing to the strike. The work on the 33-knot destroyer *Zulu*, an improved *Ghurka*, has just been started at the Hebburn shipyard. The material for the turbine machinery and boilers of the battleship *Collingwood* is all in the workshops at St. Peter's, but owing to the labor trouble no machine work has yet been

done on it. Of the first-class torpedo boats *Nos. 21* and *22*—built—and *Nos. 33* and *34*—building—the first mentioned has been tried at sea, but progress has been stopped owing to labor troubles; while the second vessel, *No. 22*, which has all her machinery on board, is similarly affected. To the same cause no progress has been made in the building of the boats *Nos. 33* and *34* at the Hebburn shipyard since our last report.

Palmer's Shipbuilding Company at Jarrow during the past six months has been engaged on the following work for the Admiralty: The completion of the "trials" of the battleship *Lord Nelson*, which were very successful, the ship having since remained alongside the works for final completion. The construction, still in hand, of the 33-knot torpedo-boat destroyer *Viking;* the successful launching and preparation for her trials of first-class torpedo boat *No. 24;* the similar class boats *Nos. 35* and *36* are now on the stocks. It is to be noted that, owing to the strikes of engineers and shipyard workers, work on the above-mentioned vessels has, as a consequence, been much delayed, and it may be truly stated that but for this the battleship *Lord Nelson* would have been handed over to the Admiralty.

Passing from the Tyne to the Thames, there being no warship work on the *Humber*, we find that such work has also practically left the Thames, Messrs. Yarrow & Co., formerly of Poplar, having migrated to Scotstoun, Glasglow, and Messrs. Jno. I. Thornycroft & Co. from Chiswick to Southampton. Following the usual routine of our notices of warship work completed or in progress, we next record that effected in the past half year by the Southampton firm. Having stated in our last report the actual results attained by the ocean-going destroyer *Tartar*, built at the works at Woolston, Southampton, on her preliminary and official trials, we now record that she was completed and handed over to the British Admiralty last April.

The *Amazon*, another vessel of the *Tartar* type, but with more power and greater displacement, now in hand, will be

launched with boilers and machinery on board in the course of a few weeks, her internal work being in an advanced stage. The *Nubian*, a similar vessel to the *Amazon*, is on the stocks and in a forward condition. Of the torpedo boats being built or completed at Woolston, *No. 19* has completed her official trials very satisfactorily—the contract speed being exceeded—and was handed over early in June. *No. 20* has completed her preliminary trials, and is now ready for her official runs; her completion for sea and delivery will be effected within the next few weeks. Two other torpedo boats in hand for the British Admiralty, *Nos. 31* and *32*, are in an advanced state, and will take the water in the course of the next two months. All the vessels above mentioned are adapted to burn oil fuel, and their turbine machinery has been, or is being, constructed at Messrs. Thornycroft & Co.'s Southampton Works, where in future it is intended to construct all boilers, the shops and plant having been removed from Chiswick for this purpose.

Cammell Laird & Co., Limited, of the Shipbuilding and Engineering Works, Birkenhead, have, since our last record of their work, completed and handed over to the Admiralty the sea-going destroyer *Cossack*. The similar but faster vessel *Swift* is now nearly ready for her trials.

At the shipbuilding works of Vickers, Sons and Maxim, Limited, at Barrow, the keel plate of the battleship *Vanguard*, an improved *Dreadnought*, was laid on the 2d of April. The tender for the building of a similar vessel, the *Rodney*, by the firm, has also been accepted by the Admiralty, and the order to proceed with its construction has been given. This vessel will have a displacement of 20,000 tons, and will be armed with ten 12-inch guns and several others of smaller caliber. She will be the fourth battleship built at Barrow for the British navy.

J. Samuel White & Co., Limited, at East Cowes, have delivered during the past six months the torpedo-boat destroyer *Mohawk* and torpedo boats *Nos. 13*, *14* and *15* to the Admiralty; *No. 16* has finished her trials and is now being

completed for sea; and the destroyer *Saracen*, built by the firm has been launched.

Yarrow & Co., Limited, since their removal from Poplar to Scotstoun, Glasgow, inform us that since the end of last year the second and third destroyers, *Nafkratoussa* and *Lonki*, built for the Greek Government, have left their works at Poplar, and have safely arrived at Athens. The fourth vessel, the destroyer *Sfondoni*, has also been handed over to the Greek authorities, and is expected to leave the Thames shortly. The "Yarrow" boiler constructed for the Spanish gunboat *Marques de Molins* has been forwarded to Lisbon; the ten sea-going torpedo-boat destroyers for the Brazilian Government are still under construction, four of them being well advanced, and one, it is hoped, will be launched in a couple of weeks. The two motor boats constructed for the Austro-Hungarian Government have just run their trials successfully. They are 60-feet long by 9-feet beam, and have a contract speed of 22 knots.—"The Engineer," July 10, 1908.

TORPEDO EXPERIMENTS ON THE MONITOR *FLORIDA*.

The monitor *Florida* was subjected to torpedo fire on the morning of June 13. She was anchored in about fifteen feet of water off Sewell's Point in Hampton Roads. A torpedo loaded with 200 pounds of guncotton was fired from a barge 400 feet distant. The place at which it was aimed was below the armor belt amidships on the port side, and the part of the vessel around it was protected by spars, etc., so that, had the torpedo gone wide of its mark, by any mischance, other parts of the monitor would have been protected. On the interior the vessel was protected with a watertight bulkhead, especially constructed, and a test of which was one of the objects of the experiment.

As the torpedo struck the monitor reeled to starboard, an immense column of water shot up to probably 150 feet in the air, the vessel then settled over to the port side.

An examination showed that a hole "large enough to admit an automobile" had been made in the side below the armor belt, the coal bunker had been blown to pieces, allowing the water to enter and fill the first watertight compartment; two other watertight compartments were damaged enough to admit water, though this damage was not very serious; there was a slight displacement of the armor, but otherwise it was uninjured; the spars and other protection for the vessel in the vicinity of the explosion were wrecked.

The machinery of the vessel was not injured, however. The pumps were immediately set to work and kept the water from entering beyond a certain depth. The *Florida* was taken immediately to drydock at the Norfolk Navy Yard and careful examination made. The results are not divulged by the Navy Department. It is said that the experiment was a success in every way and that valuable information was gained.

The only similar experiments of which there is record were made upon the British ship *Belle Isle*, in February, 1902.

—Abstracted from "New York Times."

TORSION METERS AS APPLIED TO THE MEASUREMENTS OF THE HORSEPOWER OF MARINE STEAM TURBINES.*

By J. Hamilton Gibson.

When a revolving shaft transmits power it always twists slightly throughout its length. In other words, the end at which the power is applied moves slightly in advance of the end where the work is done, the amount of twist varying directly as its length, directly as the moment of the load applied, inversely as the rigidity of the material, and inversely as the fourth power of its diameter, the formula reading—

$$\theta \times \frac{10.2\,TL}{CD^4},$$

where θ is the angular displacement in radius, $T =$ twisting moment in inch pounds, $L =$ length of shaft in inches, $C =$

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the modulus of rigidity, and $D =$ diameter of shaft in inches. The law holds good absolutely for all shafts which are not stressed beyond the elastic limit. As shafts are usually designed with a large factor of safety, it follows that the amount of twist, or the "torque," as we prefer to call it, is very small. In propeller shafting, for instance, the torque is rarely more than 1 degree for 10 feet of length, so that for a 12-inch shaft the circumferential displacement is only about ⅛ inch at full power.

Various methods and numerous instruments have been devised to enable an observer to read off the torque of revolving shafting, and such instruments are rightly termed "torsion meters," or, if self-registering, "torsion indicators." Many of these instruments are extremely ingenious, and it is proposed in this paper to briefly examine and describe some of them.

The rapidly-growing adoption of steam turbines for ship propulsion has created a demand for some ready means of ascertaining their horsepower, and as the steam-engine indicator is not suitable for this purpose, we are thrown back on a torsion meter as the only known method by which such information can be obtained. The power of a steam turbine may be estimated approximately by calculating the amount of water passed by the feed pumps, or by measuring the number of heat units that pass through the turbines in a given time; but a coefficient of efficiency must be first determined, and no account is taken of the revolutions in such estimates. As, however, "revolutions" is the very essence of power in dealing with the question of ship propulsion, that would be a very unsatisfactory method of reporting the power from a shipowner's point of view. How often do we hear the claim made that so-and-so's feed heater, for instance, has given a liner an extra one or two revolutions on the same coal consumption as before? Observe there is no mention of power, because it is recognized that, under similar conditions, the maintenance or improvement of the revolutions is the only thing that matters.

Now, it is a well-known fact that a turbine, unlike a reciprocating engine, passes almost as much steam when standing as when revolving at full speed; and it has, therefore, become an almost imperative necessity, in fixing the responsibility as between the boiler and the turbine, to know what power the turbine is transmitting to the propeller under varying conditions. The power thus ascertained is called the "shaft horsepower," in contradistinction to the term "indicated horsepower," which has come to be applied exclusively to the results obtained by "indicating" the mean pressures in the cylinders of a reciprocating engine. In this connection, "brake horsepower" and "shaft horsepower" are, of course, identical.

A small propeller working deeply immersed in smooth water is a fairly-uniform brake, and the turning moment of a steam turbine is also very uniform. Consequently there is little, if any, fluctuation of the torsional stresses in the propeller shafting. If, then, we can ascertain the torque at only one point in each revolution, it may be assumed that, knowing the revolutions, we have all the information required to calculate the work done. It is very different, however, in the case of reciprocating engines. The turning moment is anything but uniform; there are several points of maximum and minimum torque in each revolution; in fact, it is not an unknown experience to find that at one or more points in each revolution the torque is negative—that is, the propeller, acting as a flywheel, overruns the engine, and actually pulls the engine round after it. In all cases of reciprocating engines, therefore, it becomes necessary to read off the torque at several points in the revolution; the more points the better. The mean torque is then taken in making calculations of power. For a clear appreciation of the problem of torque measurement it is expedient to keep the foregoing facts well in mind, and principally to remember that we are dealing with extremely minute angles, for it is no exaggeration to say that an error of a hair's breadth may mean a difference of several hundred horsepower in the result.

Before applying any form of torsion meter to a shaft we must know its "modulus of rigidity"—that is how much it will twist with a given static load applied at the end of a lever of known length. This can only be done satisfactorily in the workshop, preferably on a long, rigid lathe-bed. One end of the shaft is securely fixed, and a twisting moment applied at the other end. To eliminate the effect of friction in the supporting bearing at the free end it is advisable to use two levers, one at either side, and the loads are preferably applied by graduated spring balances. Two pointers independent of the load levers are secured to the shaft, as far apart as practicable, and the difference in the angular movement of these two pointers gives the true twist for that length of shaft. If the pointers are made 57.3 inches long from the shaft axis, their ends will describe 1 inch of arc for 1 degree of twist, and a decimally-divided straight edge will then measure the twist to within $\frac{1}{100}$ degree, which is quite near enough for all practical purposes, and we can proceed to calculate the modulus of rigidity from the formula.

Observe that a propeller shaft is subject to two distinct stresses. Not only is it twisted as between the engine and the propeller, it is also compressed longitudinally by the propeller thrust, the compressive stress being sometimes as much as 20 per cent. of the shear stress at the surface of the shaft, produced by torsion alone. This compression augments the torque by an appreciable amount, which has been actually measured in numerous experiments, and may be taken roughly as 3 per cent. for hollow shafts and 1 per cent. for shafts which are solid. It might be considered sufficient to calibrate only one shaft in a multiple-screw vessel; but it is found that similar shafts, with identical tensile and elongation tests, have different moduli of rigidity, probably due to their varying elastic limits and some slight difference of homogeneity in the material. The only way, therefore, to ensure accuracy is to calibrate each shaft separately and to build up a power diagram for each.

Another point to bear in mind is that a working propeller

shaft is "alive," and this condition must be imitated as far as possible during calibration, by jarring the shaft with repeated blows of a mallet, so as to keep the mass in a state of molecular vibration. Otherwise the phenomenon of mechanical hysteresis, so marked in some static experiments, will obtrude itself and vitiate the results.

Having established the true modulus of rigidity for each shaft, we may proceed to build up our power diagrams based on the formula

$$H = \frac{\theta D^4 N}{CL},$$

where H = shaft horsepower, θ = torque in degrees, D = diameter of shaft in inches, N = number of revolutions per minute, C = constant varying with the modulus of rigidity, and L = length of shafting in inches. In this formula we have all the elements for obtaining the shaft horsepower, and it only remains to ascertain the number of degrees of torque by means of a reliable and accurate torsion meter. Naturally, a mechanical engineer would employ mechanical means for the purpose—in the first instance, at any rate—and we will describe two such means that have been tried with varying success.

Dr. Fottinger's apparatus has been used on several German boats, and consists essentially of two stiff tubes encircling, but free of, the shaft, except at their remote ends, where they are rigidly secured to the shaft. The free ends of the two tubes are brought together and terminate in a pair of disks, the disk revolving with the shaft in parallel planes. Assuming the disks to be 2 feet in diameter, and the two points on the shaft to which the tubes are secured to be 10 feet apart, the edges of the disks will then have about ¼ inch movement relative to one another at full power. Means are introduced to multiply this movement by the employment of links and levers, and the torque is recorded by an indicator pencil moving round a fixed paper cylinder concentric with the shaft. When there is no torque, the line drawn by the pencil is a continu-

ous circle in the same plane, and this line represents the zero, or base line, from which the subsequent torque indications are measured. When the shaft transmits power "ahead," the indication for varying torque, as in a reciprocating engine, is a wavy line on one side of the base line. For "astern" power the indication is, of course, on the opposite side. The backlash of the link work is taken up by light springs to steady the pointer or pencil.

Several diagrams taken by a Fottinger meter were shown, which exhibit clearly the fluctuating torque of shafting driven by reciprocating engines, and at full power a negative torque is seen, as previously referred to, at that period of the revolution where the propeller overruns the engine.

Another form of mechanical torsion meter is that of Mr. Collie. Instead of tubes encircling the shaft, which are limited in length by the distance between the couplings and the plummer-block bearings, two light countershafts, parallel to the main shaft and driven from it at their remote ends by sprocket wheels and chain gearing, are carried overhead. Their free ends are screwed into each other, one of them forming the nut and having a limited longitudinal movement, whilst the other has none, merely revolving in a small thrust block. As one end of the main shaft revolves slightly in advance of the other, the countershafts screw themselves into or out of one another, according to the direction of rotation of the main shaft, by an amount depending on the power transmitted. The longitudinal movement is transferred to a pointer and rendered visible on a dial which is graduated on either side of the zero into so many degrees of torque "ahead" and "astern." The backlash of the gear is taken up by springs, as in the Fottinger meter, and it is a simple matter to add a continuous recording apparatus if such be required.

As a variant on the concentric tube and countershaft methods of measuring the twist of a shaft by means of a parallel member not exposed to torque, several inventors have made use of the fact that some main shafts are hollow and fit an inner shaft loosely fitting the bore. One end of the in-

ner shaft is secured to the main shaft, and to the other end is fitted a pointer or spider, the radial arm of which emerges through grooves cut in the face of a coupling between the coupling bolts. The spider shows the same movement as the remote fast-end of the inner shaft, and moves relatively to the coupling at which it emerges. Various devices are adopted to show and record the relative movement which, of course, gives the torque of the main shaft for the length of the inner shaft.

The best-known electrical torsion meter is the Denny-Johnson apparatus. Briefly, it is made up of two revolving armatures, secured to the shaft as far apart as possible. Each armature has a pointed or chisel-shaped magnet which moves over, but does not quite touch, a finely-wound coil. The coils are connected up in series through a Wheatstone-bridge arrangement to a telephone receiver. When no power is being transmitted, the relative positions of the revolving magnets and coils are identical at each revolution, and no sound is heard in the telephone receiver. But when the shaft twists, the armatures get "out of step," as it were, and a clicking sound is heard until the pointer in the recording box is moved by an amount equal to the number of windings in the coils, indicating that one magnet is ahead, or astern, of the other, until silence again ensues, and thus the angle of torque is caught and measured.

Some time ago Mr. Gardner, of Fleetwood, made an electrical torsion meter based upon the varying amount of current permitted to flow through a wire connected up to an ordinary ammeter. Notched disks, or interrupters, are fitted to the shaft at a reasonable distance apart, and the notches are filled with non-conducting material, so spaced that the conductor and non-conductor are the same length, measured round the periphery of the disks. A brush lies lightly against the edge of each armature, the width of the brush tip being exactly equal to the length of a notch. When no torque is being transmitted, one brush is in full contact on one disk, and the other brush is adjusted so as to be just out of contact on the

other disk. Therefore, the circuit is interrupted, no current flows through the system, and the ammeter stands at zero. Immediately the shaft twists, however, the relative positions of the disks and brushes are altered, and current flows through the system until a maximum is reached, when both brushes simultaneously overlap the conductors by half their width. The widths of the brushes and notches are predetermined to register the full-power torque of the shaft.

Recently Messrs. Barr & Stroud, the makers of the artillery range finder which bears their name, have brought out a torsion meter which is apparently based on the same idea as that of the Gardner apparatus, but no details are as yet available.

Clever and ingenious as these mechanical and electrical instruments undoubtedly are, and manufactured with the greatest possible skill, they all leave something to be desired in the matter of accuracy when it comes to the measurement of power. Every link in the chain between the main shaft and the recording apparatus introduces a possible source of error, and, as has been pointed out, an error, even of the proverbial hair's breadth, means a fairly large percentage error in the horsepower result. In mechanical torsion meters the multiplying gear necessarily involves a multiplication of whatever error there might be; whilst there are more insidious causes of error which creep in in an electrical apparatus, such as variations due to battery resistance, temperature effects, slight dragging of the commutator sections and brush tips, metallic dust or damp on the contact surfaces, and so on.

We turn, therefore, to other methods, and proceed to describe those torsion meters which depend on the action of a beam of light. Herr Frahm, of Germany, and Professor Hopkinson, of Cambridge University, have been working for some time on the same lines, and each has evolved an apparatus so similar that probably the same description will suffice for both. Starting with the concentric tubes and parallel disks of Fottinger's mechanical apparatus or their equivalent, the link work for recording purposes is dispensed with, and a

small plane mirror is used, pivoted to the edge of one disk and oscillated by a projection on the other disc. As the relative movement between the disks increases, so the plane of the mirror is altered. A beam of light from a fixed lamp is projected on to the edge of the disks, and at each revolution of the shaft it is caught on the mirror and reflected on to a graduated scale. In a dark chamber, such as a shaft tunnel, the streak of light from the mirror on the rapidly-revolving apparatus is almost continuous, and the graduations are read off with tolerable ease; but the almost inevitable spreading of the light beam adversely affects the accuracy of the reading.

Mention should be made of a torsion meter invented by Amaler, of planimeter fame. A concentric sleeve is fitted on the shaft, and the free end brought close up to a fixed collar. A short scale is engraved on the collar, and a pointer or vernier on the free end of the sleeve, something like the marks on a micrometer caliper gauge. As the shaft twists, the pointer moves along the scale. The problem now is to read the scale as it is flying round with the shaft. Here advantage is taken of the instantaneous duration of an electric spark. Contacts are fitted on the shaft just in advance of the scale, and a spark throws a powerful light on to the polished scale once in each revolution, so that the scale, however fast the shaft is revolving, appears to stand still, and thus the torque in degrees is read off directly.

The Bevis-Gibson flashlight torsion meter has undergone searching tests during the last eighteen months. Starting with the well-known physical facts that the velocity of light is practically infinite, and that light rays travel in absolutely straight lines through air of even density, it was conceived that some simple means of applying these principles to a solution of the problem of shaft torque should be forthcoming. The usual trial and error work with which inventors are so painfully familiar followed, and eventually the flashlight torsion meter was evolved and put into use. By a mental process of elimination, it was decided at the outset that the less "gear" the better. The angles to be measured are so incon-

ceivably minute, and in a rapidly-revolving shaft the time intervals are so inconceivably short, that nothing but an absolute direct reading can give a true result.

The method adopted can be best shown by a diagram. Two blank disks are mounted on the shaft at a convenient distance apart. Each disk is pierced near its periphery by a small radial slot, and these two slots are in the same radial plane when no power is being transmitted, and there is no twist on the shaft. Behind one disk is fixed a bright electric lamp masked, but having a slot cut in the mask directly opposite the slot in the disk. At every revolution of the shaft, therefore, a flash of light is projected along the shaft towards the other disk. Behind the other disk is fitted the torque finder—an instrument fitted with an eye-piece and capable of slight circumferential adjustment. The end of the eye-piece next its disk is masked, except for a slot similar and opposite to the slot in the disk. When the four slots are set in line, a flash of light is seen at the eye-piece every revolution, and if the shaft revolves quickly enough the light will appear to be continuous. This effect is apparent at anything over 100 revolutions per minute. At lower speeds the flash is seen to be intermittent, but this in nowise affects the accuracy and reliability of the result. At each end of the shaft, therefore, we have what is virtually an instantaneous shutter fixed, be it noted, directly to the shaft, and there is no connecting link or gear between the disk, either mechanical or electrical, except the beam of light which flashes once in each revolution clear through the two shutters. Let us suppose now the shaft to be transmitting power. One disk lags behind the other by a definite amount, and although three of the slots are still in line, the fourth slot—namely, that in the lagging disk—effectually blanks the flash and no light is seen at the eye-piece.

This is where the function of the torque finder comes in. To pick up the light again the eye-piece must be moved by an amount equal to the circumferential displacement of the lagging disk. This is accomplished by manipulating the mi-

crometer spindle of the torque finder, on which is a scale and vernier graduated in degrees. While the scale is fixed its vernier moves with the eye-piece, and the graduations are so marked that by the aid of a simple microscope, conveniently hinged, differences of $\frac{1}{100}$ degrees can be readily discerned. For shafts of ordinary size the scale is set 13.6 inches radius from the center of the shaft, so that the degrees are about $\frac{1}{4}$ inch apart. One-hundredth of a degree, therefore, means one-hundredth of $\frac{1}{4}$ inch, or $\frac{1}{400}$ inch. As an ordinary shaft twists 1 degree in 10 feet at full power, it is, therefore, possible to get the shaft horsepower to within 1 per cent. of full power. But as it is frequently possible to fit the disks 40 feet or 50 feet apart, even this accuracy may be improved upon, and powers ascertained to within one-quarter of 1 per cent. of full power. Users of the ordinary steam-engine indicator will readily appreciate what this means, for indicated horsepowers are frequently woefully erratic. When we consider that a steam-engine cylinder is often some thousands of times greater in area than the small indicator piston, we get some faint notion of the effect of multiplication of error. Add to this the friction of the engine piston, the piston rod, the guides, and the connecting-rod joints, and we begin to realize how much more reliable is shaft horsepower than indicated horsepower. For purposes of scientific data, especially in reference to ship propulsion, the latter term will, no doubt, soon become obsolete, and retire into the comparative obscurity of nominal horsepower and other like terms.

The slots in the torsion-meter disks are necessarily of appreciable width, and in moving the torque finder over, the light is visible for some distance along the scale. The light comes into view, attains a maximum amplitude and brightness, and fades away as the eye-piece moves along the scale. If it were possible to gauge the exact point where the light attains the maximum, that is the point that would be used. Failing this, however, use is made of one edge of the slot. The finder is moved always in the same direction in taking readings, and stopped at the exact point where the light is cut off. So del-

icate is the sense of sight that a movement of $\frac{1}{100}$ degree is sufficient to mark the difference between light and darkness. A zero reading is taken when the shaft is revolving idly—if possible, at or near full speed—and this reading forms a base and is subtracted from any subsequent power readings.

Let us see how this works in practice by employing a mechanical lantern slide. First, suppose the shaft to be revolving idly. The finder is moved over until the light is just disappearing, and the vernier is seen to be standing at 0.53 degrees. Now suppose the shaft to be transmitting power. The disks have twisted relatively to one another, and no light is seen until the torque finder is moved the same amount. Having picked up the light the finder is worked gently over until the light is just disappearing again. The reading is now 2.39 degrees. Subtract from this the zero reading of 0.53 degrees and we get the true torque—namely, 1.86 degrees. Now to apply our shaft-horsepower diagram. We will suppose that the revolutions are 475 per minute. The torque is 1.86 degrees, and, finding the intersection of the lines on the diagram, the power is seen to be 3,620.

It is, perhaps, scarcely necessary to point out that the whole operation takes much less time than its description. Indeed, it is possible to produce the shaft horsepower on a trial trip immediately on the termination of each measured-mile run, and to hand a slip to the officer in charge, containing all the information, in plenty of time for him to make any necessary adjustments before coming back on the straight for the next mile.

For reciprocating engines a simple modification of the flash-light torsion meter enables the operator to take several readings—usually twelve—in one revolution of the shaft. The disks are perforated with twelve slots arranged in the form of a spiral—one at each 30 degrees of the circumference. The lamp and torque finder must be moved radially from the shaft, so as to bring them into line with each corresponding pair of slots in the disks. By spotting the readings on a sheet of squared paper and sketching in the curve, we get an actual

twisting-moment diagram, from which the mean torque is readily obtained. The mean torque with the revolutions is then referred to the power diagram, and the shaft horsepower read off as before.

Table I.—FLASHLIGHT TORSION-METER RESULTS.

Engines, No. 1215.

Vessel, H.M.S. *Indispensable*. Date, 31st December, 1907.
Trial, Official Full-Power. At Clyde.

Shaft.	Run.	Steam at H.P. receiver, lbs. per sq. in.	Revolutions per minute.	Reading.	Torque, degrees.	Shaft horsepower.
Starboard, wing	IV.	180	710	5.90	1.26	8,300
center			680	6.02	1.20	7,480
Port, center			687	4.64	1.21	7,520
wing			707	5.74	1.23	8,270
Mean revolutions	...	...	696		Total	31,570

The modification of the apparatus is only required in the case of shafting driven by reciprocating engines. In a recent vessel a comparison in this connection was made. A crank-effort diagram was built up, in the usual way, from the indicator diagrams, due allowance being made for the effect of the inertia of the moving parts, and the torsion-meter twisting-moment diagram drawn down to the same scale. The latter curve corresponds closely with the crank-effort diagram, but the variation from the mean is greater in the shaft-torque diagram, due, probably, to the action of the propeller and the torsional oscillations thus set up. It will be noticed that the dotted shaft diagram is consistently below the crank-effort diagram, the mean difference being about 10 per cent. This difference corresponds almost exactly with the result obtained by steaming, and indicating the engines disconnected from the propeller in the wet basin before the underway trials, and forms a striking check and corroboration of the two curves. Cases sometimes occur, especially in modern warships, where

a long length of shafting is not available for torsion-meter purposes, and recourse must be had to a special form of apparatus.

To meet this contingency another modification of the flash-light torsion meter is used, in which the beam of light, instead of flashing axially along the shaft, is made to flash radially through slots in concentric drums, and is caught by a torque finder at a distance from the shaft. The drums are fixed to the shaft only 2 feet or 3 feet apart, and the relative movement due to shaft torque is naturally very much less than that of the discs in the actual form of torsion meter. A masked lamp is fitted inside the smaller drum next the shaft and so close to the drum that when the shutter opens the source of light is exactly at the shutter. The outer drum is made as large in diameter as can be conveniently arranged, the radial distance between the drums, as compared with the distance of the torque finder from the source of light, giving by direct proportion the required multiplication of effect, and enabling the torque, as before, to be read off with extreme accuracy, considering the short length of shaft available. The light in this case is cut off by the three knife edges—one at the lamp, one at the inner drum and one at the outer drum—the eye-piece being fitted with a diaphragm pierced by a minute pin hole in the center. The extreme sensitiveness of the apparatus is almost incredible. The angle of the flashing beam proceeding radially from the shaft can be measured to $\frac{1}{1000}$th of a degree, so that although only 3 feet of shafting may be available, the result is as good as if a 30-foot length had been used with an axial-ray apparatus.

Radial-flash torsion meters are not quite so simple in construction as the axial-flash type; but there are certain obvious advantages besides its applicability to a short length of shafting. For instance, the flash might be led vertically upwards through a tube in a deck immediately overhead, and the readings taken at will in the seclusion that a cabin grants, instead of in the engine room or tunnel. In the practical application of the flashlight torsion meter to various vessels

fitted with steam turbine installations some very interesting results have been forthcoming, which are set out in tabular form in Table II.

Table II.—TURBINE STEAMER.

FLASHLIGHT TORSION METER. ACTUAL READING AND CORRESPONDING HORSEPOWERS TAKEN DURING TRIAL TRIPS UNDER VARYING CONDITIONS OF DISPLACEMENT AND PROPELLERS.

Turbine shaft.	Torque, degrees.	Revolutions per minute.	Shaft horse-power.	Shaft horse-power, total.
Starboard, low-pressure	1.43	482.9	2,775	7,975
Center, high-pressure	1.69	461.2	2,600	
Port, low-pressure	1.37	472.8	2,600	
Starboard, low-pressure	1.32	461.2	2,410	6,940
Center, high-pressure	1.65	426.8	2,330	
Port, low-pressure	1.24	457.3	2,200	
Starboard, low-pressure	1.15	426.4	1,970	5,960
Center, high-pressure	1.52	417.6	2,080	
Port, low-pressure	1.13	418.9	1,910	
Starboard, low-pressure	1.05	418.4	1,765	5,555
Center, high-pressure	1.52	422.3	2,120	
Port, low pressure	1.02	415.5	1,670	
Starboard, low-pressure	0.21	198.6	162	495
Center, high-pressure	0.27	206.3	185	
Port, low-pressure	0.19	183.5	148	
Starboard, low-pressure	0.22	146.7	88	257
Center, high-pressure	0.21	171.4	87	
Port, low-pressure	0.13	144.8	82	
Starboard, low-pressure	0.07	46.3	13	37.2
Center, high-pressure	0.05	86.1	15	
Port, low pressure	0.01	24.4	9.2	

Attention is specially directed to the immense range of the apparatus. Some of the low powers recorded are less than half of 1 per cent. of the full power. If indicated horsepowers of such small amount were required to be taken from a piston engine, the indicator spring would have to be changed for a very weak one to get a reasonably accurate card; but no such change is required in the apparatus we are considering.

Then, again, the distribution of power in a turbine installation can only be approximately estimated. The steam is turned into the high-pressure turbine and left to follow its own devious course through the successive turbines on its way to the condenser. At low powers it is sometimes found that the high-pressure turbine shows the most power, whilst for overloads the lower-pressure turbines have the advantage. The percentage distribution of power is shown by three sets of figures—for a three-shaft turbine installation, including high-pressure and intermediate cruising turbines. Set A shows the estimated or designed distribution, set B the calculated distribution from the pressure-gauge readings at the terminals of each turbine, and set C shows the actual distribution of power over the three shafts as ascertained by flashlight torsion-meter readings.

Referring again to Table II, it will be seen that the starboard low-pressure turbine shows throughout the series more power than the port. Investigation showed that the blade-tip clearances of the two turbines differed slightly, and a further comparison proved that the percentage difference of clearance was just sufficient to account for the differences of shaft horsepower recorded.

In a recent progressive trial of a vessel fitted with triple-expansion engines, flashlight torsion-meter readings were taken at varying speeds. Plotting these results in the manner before described, we notice an almost alarming fluctuation of torque as the power increases, and at one point—namely, where the intermediate crank is at right angles coming up, and the low pressure has just opened full to steam on the downstroke, the high pressure being just past cut-off—the propeller overruns the engine and the torque is negative.

Other observations and comparisons might be made; but enough has been said to indicate the advantages and possibilities of shaft horsepower results, and we must conclude that, whichever type of torsion meter comes into general use on the inexorable principle of "the survival of the fittest," the torsion meter in some form or other has come to stay.

THE INTERNAL-COMBUSTION ENGINE.

By W. G. WINTERBURN, M. I. N. A., Victoria, B. C.

The probability of motor launches being added to the equipment of modern steamships in the near future necessitates the addition of yet another subject to the enclyclopedic knowledge required of the present-day marine engineer. For those who have not given the subject much thought as yet, I propose to give an elementary description of the gasoline engine as used for propelling small vessels.

General principle.—The action of the internal-combustion may be likened to the discharge of a gun: imagine the cartridge to have the shell extended forming a trunk piston; a connecting rod is suspended from the nose of the bullet, its other end attached to a crank outside the barrel; on the crankshaft is fitted a heavy flywheel.

When the detonator is struck it explodes the charge, the reaction of which drives out the bullet, but, being trammelled by attachment to the crank, transmits its energy to the flywheel, which in turn drives the bullet back up the barrel. In the motor, the piston on its return stroke draws in a mixture of gas and air, which is compressed to a point which renders it highly explosive; at this juncture the electric spark, corresponding to the cap in our simile, is flashed and explodes the gas; this gives the piston the impulse which puts kinetic energy into the flywheel for returning the piston, besides doing the work required of the engine.

In the four-cycle motor the charge is admitted to the cylinder and exploded, driving the piston to the end of the stroke—cycle 1. The momentum of the flywheel drives the piston back; during this period exhaust valves open and the spent gases are driven out of the cylinder—cycle 2. The energy still left in the flywheel drags the piston outward another stroke, during which inlet valves open and admit a new charge of explosive mixture—cycle 3. The flywheel again drives the piston back, compressing the gas ready for a new explosion—cycle 4.

In the two-cycle motor the incoming gas is made to sweep out the old and spent gas and an explosion is obtained every revolution; it is not a good mechanical proposition but works well for small power, and as it does away with a number of valves at the attachments for operating them, the mechanism is simplified and first cost reduced.

The operation is this: The gas is admitted and exploded, driving forward the piston; at a point in the stroke the piston uncovers a port in the cylinder wall which permits egress of the exploded gas; another port on the opposite side is uncovered through which rushes new gas which had been confined under pressure, a deflector is cast on to the top of the piston which directs the rush of new gas to the cylinder head, whence it recoils with sufficient rapidity and force as to drive before it the spent gas without commingling with it to any appreciable extent; the return stroke of the piston compresses the new gas, which is then exploded and another impulse given to the piston.

It will be seen that the two-cycle engine requires a lighter flywheel and considerably less mechanism than the four-cycle, but it is not reliable for varying loads and will not stand up to continuous heavy work so long as the latter; also, it is less economical in fuel, as a portion of unspent gas must pass off with the exhaust, whilst a residuum of the latter remains in the cylinder, causing incomplete combustion by adulterating the explosive mixture.

Reversing.—Generally, the engine is intended only to run in one direction, the astern motion being effected either by changing the angle of the propeller blades or by a reversing clutch. There are many forms of reversible propellers on the market, any of which may be applied. The reversing clutch consists of a train of gears, by means of which the direction of rotation of the shaft is reversed, and is identical with the arrangement used in motor cars. In practice, the solid propeller with reversing clutch has been found the more efficient of the two systems, but the noise made by the gearing is objectionable.

The engine itself will reverse if the explosion is timed at the right moment; if, for instance, the revolutions are in the direction of the hands of a clock and the spark is ignited at two minutes past twelve, the piston receives its impetus and the crank revolves in the normal direction; if now on the return stroke the spark ignites at two minutes *before* twelve, the crank will not turn the center, and the piston is forced back, and as long as the spark occurs at this point the engine will run that way. In practice it was found that motors could be reversed by this means when running free, but not with a load on; so a releasing clutch has been devised which disconnects the shaft while the position of the sparker is being altered, it is thrown into gear when the engine starts to go in the direction required.

Cooling.—The heat generated in the cylinder is great and is usually dissipated by means of water circulating round it; in land engines circulation is obtained by gravitation, a cooling tank is placed a few feet above the engine into which the hot water discharges, the cooler water returning to the jacket from the bottom of the tank; for marine work a pump is necessary. Care must be exercised in frosty weather to see that jackets are drained when the engine is not being used. In very cold climates winged radiators cast on the cylinder are preferable to water cooling.

Vaporizer, as its name implies, is an instrument for changing the liquid fuel to the gaseous form; it consists of a brass vessel containing a float and a needle valve; these are so adjusted that air is admitted in the exact proportion to the quantity of gasoline passing through the valve, in order to make the correct mixture for explosion. If an excess of gasoline is supplied the mixture is said to be "too rich," and either the cylinder is flooded with liquid gasoline and the electric terminals wetted, killing the spark, or incomplete combustion takes place and black smoke of offensive odor is emitted from the exhaust, and the working of the engine is weak and erratic, and if too much air enters the gas will not explode at all. An induced draft to the cylinder is created

by the motion of the piston and the gasoline is drawn through fine perforations in the vaporizer, which breaks it into a minute spray when the mixture with air takes place. Once the float-and-needle valves have been correctly adjusted they should not be interfered with except when atmospheric or temperature changes make re-regulation necessary. A butterfly-throttle valve forms part of the device which is operated by a hand lever and the speed of the engine is thereby controlled.

Sparking.—Although theoretically explosion will occur automatically when a given pressure and temperature agree with the right chemical combination, in practice all the precise conditions cannot be relied upon to ensure regular action. An electric spark is utilized to ignite the gas; a plug containing insulated wires is screwed into the cylinder end. The terminals consist of two platinum points with a gap between of about one sixteenth of an inch; the current is conducted through cables to the plug, first passing through the timer. This is a device operated by the engine which opens and closes the circuit; when the circuit is closed the electric fluid jumps the space between the terminals of the plug and a spark is generated in the same manner as the arc light. By altering the position of the timer an early or late spark can be obtained and the explosion timed to take place at the moment most suited to the conditions. Sometimes, instead of the plug, what is termed the "make-and-break" system is adopted; this is an arrangement whereby a reciprocating part of the engine causes a pawl to oscillate within the clearance part of the cylinder; on this is fitted a platinum point which bears against an electrode screwed through the cylinder cover or head; when the movement of the pawl breaks the contact with the electrode the current tries to follow and so creates a spark. The heat and intensity of the spark is a most important desideratum. When two spark plugs are fitted to one cylinder much better combustion results, besides the advantage of increased reliability due to duplication.

Electric current is generated in the first instance in a set

of dry cells, or a battery of the Lalande type. Four cells of about 18 ampères make a good battery for a 3-H.P. motor; these are either placed in a convenient locker and connected in series, or the set can be obtained fitted into a box and encased with hard wax; this is a portable and watertight arrangement, and very suitable for marine work on account of the perfect protection from damp and other destructive agents prevalent on board vessels. The life of dry batteries depends a great deal on weather conditions and changes of climate; they will not last longer than a few months, even when the motor is little used and not consuming current, and as they die practically of senility, it does not avail to carry spare cells, as they also will be found weak when wanted. Being cheap and easily replaced is in their favor when near sources of supply, but for remote places or long voyages a renewable battery is desirable.

The Lalande type consists of jars containing zinc and copper-oxide plates suspended in a solution of caustic soda; on this floats a thin layer of oil to check evaporation. These batteries retain their voltage until exhausted, and when it is necessary to renew the constituents it is an easy matter to remove the wasted metals and pour in fresh solution; the battery is then as good as new. Renewals can be kept idefinitely, as, of course, no chemical action takes place until they are combined.

For continuous working, a magneto or sparking dynamo is often fitted; the engine is started with current from the chemical battery, and when fairly away this is switched off and the magneto brought into operation. The best way of driving this is by friction pulley bearing on the flywheel and held thereto by springs. Belts require constant tightening and gearing is noisy.

The coil.—The current generated by the batteries is of low potential and has to be transformed into high tension in order to produce spark of the required intensity. The current is led by "primary" insulated cable to the coil, which gathers up electro-magnetic energy which is released when the vi-

brating points are separated; the "secondary" cable conveys the current thence to the spark plugs or electrodes within the cylinder. In multiple-cylinder engines special coils are required with terminals for each, or individual coils for each cylinder, the units being interchangeable.

Lubrication.—In all high-speed engines this is a most important factor. For the internal parts care must be taken that only best quality gas-engine oil is used, and the oil must be fed continuously. It passes through sight-feed lubricators and the drops can be regulated with the greatest nicety. An excellent method of feeding is where a reservoir, holding, say, a quart, is fitted in a convenient corner having a pipe connection to the crank case, where always exists a slight pressure; this forces the oil up to the sight-feeds and the amount admitted to the cylinder, etc., is regulated by stop cocks. The wrist pin passing diametrically through the piston is bored hollow and gathers oil from the oil orifice in the cylinder wall as it passes. By this means not only the pin is lubricated, but the surplus oil flows down a channel in the connecting rod to the crank pin; the drippings from this fall into the crank case, which, being hermetically closed, retains it, and the crank splashes it over all working parts. In the two-cycle engine, where the explosive vapor is drawn into the crank case previous to passing into the upper or working end of the cylinder, it becomes impregnated with atomized oil and arrests thereby the smooth running of the piston.

General.—When well cared for, few adjustments are found necessary in well-designed motors and they will run a long time before requiring overhaul. The thrust of the propeller shaft is taken by ball rings on the bedplate; bronze alloys are more suitable for bearings than white metal. The connecting rod in the smaller sizes is of bronze throughout, of H section; the nuts should be very securely locked and pinned; the piston is very deep, having three Ramsbottom rings above and one below the wrist pin. A muffler is necessary to drown the sound of exhaust, some engines exhaust under water, but the back pressure somewhat checks the speed. A governor

fitted within the flange of the flywheel is a useful adjunct, though not always supplied, many makers contending that single-cylinder engines are so carefully balanced as to render governors unnecessary. Multiple engines have the turning moment well distributed; this, however, does not prevent racing, and launches carried on ocean steamers do not always have smooth water to sail in.

In all parts of the world where gasoline is procurable at a reasonable price the internal-combustion engine is displacing steam for small craft. It is not necessary to recapitulate its advantages, and the objection formerly adduced that it is not perfectly dependable is answered by the fact that motor boats have crossed the Atlantic under their own power and without convoy, and motor engines are being fitted into lifeboats, which have provision for self-righting in case of capsize; the engine being enclosed in a watertight compartment and manipulated from the outside by means of rods and handles passing through stuffing boxes in the bulkhead. An engine that will comply with such conditions has surely come to stay.

NOTE ON THE USE OF SUPERHEATED STEAM WITH MARINE ENGINES.*

By Monsieur Felix F. T. Goddard, Member.

Superheated steam was used in marine engines more than half a century ago, after Hirn's noteworthy experiments with the *Logelbach's* engine in Alsace. The French Navy also tried it on some of their earliest protected cruisers.

These early attempts were not, however, followed up, as it was found difficult to construct superheaters capable of maintaining a constant and sufficiently high temperature, and also because of the wear and tear of the hemp packings in use at that period.

The introduction of compound marine engines, more eco-

* Read at the Spring Meetings of the Forty-ninth Session of the Institution of Naval Architects, 9th April, 1908.

nomical than the simple engines that had preceded them, caused the use of superheated steam to be given up for the time being. The same thing occurred with stationary engines, where improvements in valve gear enabled a high ratio of expansion to be employed and the clearances to be reduced to a very small percentage of the cylinder volume.

In the Vosges and Alsace, however, the problem of using superheated steam in stationary engines was revived some fifteen years ago. Several different arrangements were designed by Mr. E. Schwoerer, a former assistant of Hirn's, who used a massive superheater placed behind the fire bridge of the boiler furnace, and this gave such promising results that the study of the question of superheated steam was taken up by a number of manufacturers, chiefly in Germany, Alsace and Switzerland.

It was found that engines fitted with Sulzer Colman valves, which were largely employed in those countries, were very suitable for use with superheated steam. In France, where the Corliss gear was usual in stationary engines, superheating did not make much progress, because it was not suited to the Corliss engine, or, in fact, to any flat slide-valve engine. The exhibits at the Paris Exhibition of 1900 showed this to be the case.

Since then the use of superheated steam with stationary engines has increased largely, and considerable economy has been effected thereby. It is not unusual to find engines of 1,500 I.H.P. to 2,000 I.H.P. using steam at 300 degrees centigrade (572 degrees Fahrenheit) and working at an expenditure of only 4 kgms. (9 pounds) of steam per I.H.P.* per hour.

There is but little information, however, on the subject of the variation in the consumption of steam in relation to its temperature. A few years ago the author made some experiments on a triple-expansion engine with piston valves, the temperature of the superheated steam varying from 0 to 120 degrees centigrade. The results of these trials still present

* I.H.P. referred to in this paper is French "force de cheval" of 75 kgms. = .986 British I.H.P.

some features of interest. In the diagram the abscissæ represent the amount of superheat, *i. e.*, the difference between the actual temperature of the steam (in degrees centigrade) and the temperature corresponding to the pressure when the steam is saturated. The ordinates represent the weight of steam consumed per effective brake horsepower.

TRIPLE-EXPANSION ENGINE.

Diameter of cylinder	(H.P.)	0.20 m. ($7\frac{7}{8}$ in.)
	(M.P.)	0.33 m. (13 in.)
	(L.P.) 2 of	0.37 m. ($14\frac{9}{16}$ in.)
Stroke		0.29 m. ($11\frac{7}{16}$ in.)
Revolutions		440
Power		300 B.H.P.
Cut-off		0.7
Ratio of expansion		9.8
Pressure in main steam pipe	(A)	12.8 kg. (182 lbs. pr. sq. in.)
	(B)	15.0 kg. (214 lbs. pr. sq. in.)

A exhaust to atmosphere.
B exhaust to condenser.

Now, the curve A in the diagram (exhaust to atmosphere) shows that the consumption per hour of saturated steam (*i.e.*, with no superheat) is 8.85 kg. ($19\frac{1}{2}$ pounds) per B.H.P., whereas it falls to 5.70 kg. ($12\frac{3}{4}$ pounds) at a temperature of 320 degrees centigrade (608 degrees Fahrenheit), equivalent to a superheat of 120 degrees centigrade (216 degrees Fahrenheit).

The saving, therefore, amounts to—

$$\frac{8.85-5.70}{8.85}=35.5 \text{ per cent.}$$

Taking curve B (exhaust to condenser), the consumption per B.H.P. falls from 7.15 kg. (16 pounds) with no superheat to 4.85 kg. ($10\frac{1}{2}$ pounds) with a superheat of 120 degrees centigrade, or a saving of—

$$\frac{7.15-4.85}{7.15}=32 \text{ per cent.}$$

It will be seen, therefore, that superheating may lead to an economy, as compared with saturated steam, of 35 per cent. in engines of this type exhausting to the atmosphere, and 32 per cent. for those exhausting to the condenser.

The amount of reduction in steam consumption depends, of course, upon the design of the engine under consideration; in the present case it amounts to about 1 per cent. for every 4 degrees centigrade (7.2 degrees Fahrenheit) of superheat. This is a figure frequently given, and which the author has been able to verify elsewhere.

Doubts, however, have often been expressed in regard to the efficiency of superheating in actual practice. These arise from the wear of the valve gear of the engines, which causes losses that neutralize part of the economy obtained by using superheated steam.

It is now recognized by all the makers of land engines that, in order to use steam at a temperature of 280 degrees to 320 degrees centigrade (536 degrees to 608 degrees Fahrenheit), the engine friction must be as small as possible, as, for instance, in reciprocating engines with lift valves, and still more so in turbine engines.

Superheated steam is now generally adopted for land en-engines by reason of the economical results obtained in practice, which, in certain special cases, have effected a saving of upwards of 33 per cent.

For marine engines the case is very different. England was the first country to take up the matter; in 1900 Messrs. Wilson & Sons, of Hull, installed superheaters on board the S. S. *Claro*, which appear to have given satisfactory results. Other installations followed with varying measures of success. The British Admiralty investigated the question on the *Britannia* with satisfactory results.

Superheating has also been adopted in the United States on the S. S. *Creole*, fitted with Curtis turbines, and in Germany on the *Ersatz Komet* with Parsons turbines. Nevertheless, superheating in marine engines cannot be said to have gained ground as rapidly as was expected. It may, therefore, be of interest to record some very encouraging results which have been obtained in France within these last few years.

In 1906 the Société de Saint-Nazaire built two identical cargo boats for the Compagnie Générale Transatlantique.

They were the *Garonne*, fitted with ordinary triple-expansion engines and slide valves, and the *Rance* with similar engines, but with the Lentz valve gear. The boilers of the latter vessel are similar to those of the former, except that they are fitted with "Pielock" superheaters.

The leading dimensions of these two ships, their engines and boilers, are as follows:

Length	91.0 m. (298 ft. 6 in.)
Beam	12.20 m. (40 ft. 0 in.)
Molded depth	7.75 m. (25 ft. 5 in.)
Load draught	6.40 m. (21 ft. 0 in.)
Gross tonnage	2,700 tons.

ENGINES.

Diameter of cylinders,	(H.P.)	0.584 m. (23 in.)
	(M.P.)	0.914 m. (36 in.)
	(L.P.)	1.498 m. (59 in.)
Stroke		1.066 m. (42 in.)

The boiler installation of each ship consists of two cylindrical boilers, each having two furnaces and fitted with Howden's forced draft.

	Garonne.	*Rance.*
Total grate area, sq. m.	8.40 (90.42 sq. ft.)	8.40 (90.42 sq. ft.)
Heating surface, sq. m.	350.08 (3,767 sq. ft.)	277.08 (2,982 sq. ft.)
Superheating surface, sq. m.	......	73.00 (785 sq. ft.)
Total heating surface, sq. m.	350.08 (3,767 sq. ft.)	350.08 (3,767 sq. ft.)

The trials of these two vessels were carried out under conditions as similar as possible, so that the comparison of results might be quite fair, and the coal used was the same in both cases. The results of the trials were as follows:

COAL-CONSUMPTION TRIALS.

	Garonne.	*Rance.*
Date of trials	July 6, 1906.	Sept. 13, 1906.
Boiler pressure	12.6 kg. (178 lbs. per sq. in.)	12.54 (177 lbs. per sq. in.)
Steam temperature	192° C. (377.6° F.)	270° C. (518° F.)
Revolutions	72.3	75.37
I.H.P.	1,104.	1,304.
Coal consumption per I.H.P.	511 gr. (1.12 lbs.)	408 gr. (0.9 lb.)
Advantage of superheating:		
Increase of power		18.1 per cent.
Reduction of coal consumption		20.1 per cent.

Both ships were put into service directly after the trials. It is now over a year since these two cargo boats have been engaged upon an exactly similar service, and it has been possible, therefore, to obtain accurate data regarding their working and comparative coal consumption.

Taking for each ship ten trips made at corresponding dates, so as to have as far as possible identical conditions of weather, loading and quality of coal used, the fuel consumption per mile worked out at 69.981 kg. (154 lbs.) for the *Garonne* without superheating; 57.228 kg. (126 lbs.) for the *Rance* with superheating.

Comparing these figures we have an economy in coal consumption in favor of the *Rance* of

$$\frac{69.981 - 57.228}{69.981} = 18.2 \text{ per cent.}$$

There was, moreover, no trouble in either engines or boilers. No leakage has occurred in the valves, which continue to bear simultaneously on both upper and lower seatings. The superheater has not required any particular attention; a constant steam temperature has been maintained, which rises only a few degrees when additional power is required of the boilers, and falls again automatically directly the engines are stopped.

In consequence of the results of the early trials of the *Rance* the Compagnie Générale Transatlantique installed Pielock superheaters and Lentz valve gears on the S. S. *Pérou*, for service to the Antilles (West Indies), and also on the intermediate cargo boat *Caroline*. The same arrangement is being adopted on the cargo boat *Honduras*, and other cases are under consideration.

These results were considered most satisfactory both by the Postal Commission and by the owners of the vessels.

A noteworthy feature is the constant temperature of the superheated steam. This temperature was taken at admission of steam to the engines by means of a Fournier recording thermometer.

It will be seen that the variations of temperature are very

small, and do not exceed 20 degrees centigrade (36 degrees Fahrenheit) from the time of starting the engines to that of running at full power, which includes also the period of cleaning the fires.

These results are very interesting as being applicable also to the use of superheated steam in large turbines on board ship. The absence of sudden changes of steam temperature in turbine engines will prevent the apparatus from being exposed to sudden expansion and contraction, the effects of which might be serious.

From the results obtained both in England and in France, superheated steam applied to reciprocating engines conduces to considerable economy without the introduction of complicated machinery necessitating additional attention. There appears to be no reason, moreover, why superheaters of a type similar to that installed on the steamship *Pérou* should not be fitted to the large turbines of ocean liners, using only a moderate amount, say, 60 degrees to 70 degrees centigrade (108 degrees to 126 degrees Fahrenheit), of superheat. From the experience gained with steam turbines on land, at least 10 to 12 per cent. fuel economy should result from this, being 1 per cent. saving for every 6 degrees centigrade (11 degrees Fahrenheit) of superheat.

Each of these vessels is to be comparable to a sister ship, working with saturated steam, in order to follow up on a larger scale the conclusive results already obtained with the *Rance* and the *Garonne*.

The steamship *Pérou* has just completed her trials. She is identical, save for the superheating and valve gear, with the steamship *Gaudeloupe*, employed on the same service, and which was completed in September, 1907.

The dimensions of these two ships are as follows:

Length	**131.00 met. (429 ft. 9 in.)**
Beam	**15.86 met. (52 ft.)**
Molded depth	**10.50 met. (34 ft. 6 in.)**
Load draught	**6.60 met. (21 ft. 7 in.)**
Gross tonnage	**6,800 tons.**

Each vessel is fitted with twin-screw triple-expansion three-cylinder engines of the following dimensions:

		Gaudeloupe.	Pérou.
Diameter of cylinders,	(H.P.)	0.685 m. (27 in.)	0.685 m. (27 in.)
	(M.P.)	1.092 m. (43 in.)	1.060 m. (41¾ in.)
	(L.P.)	1.828 m. (72 in.)	1.828 m. (72 in.)
Stroke		1.219 m. (48 in.)	1.219 m. (48 in.)

The boiler installation of each ship comprises six cylindrical boilers having three furnaces each, and fitted with Howden's forced draft.

	Gaudeloupe.	Pérou.
Total grate area, sq. m	32.130 (346 sq. ft.)	32.130 (346 sq. ft.)
Boiler heating surface, sq. m.	1,255 (13,509 sq. ft.)	932.70 (10,030 sq. ft.)
Superheater heating surface, sq. m	......	302.00 (3,260 sq. ft.)
Total heating surface, sq. m.	1,255 (13,509 sq. ft.)	1,234.70 (13,290 sq. ft.)
Working pressure	13 kg. (185 lbs. per sq. in.)	

The speed trials of both vessels, which were carried out under absolutely similar weather conditions, gave the following results:

	Gaudeloupe.	Pérou.
Date of trials	Sept. 9, 1907.	Feb. 6, 1908.
Steam	Saturated.	Superheated.
Boiler pressure	13 kg. (185 lbs. per sq. in.)	13 kg. (185 lbs. per sq. in.)
Temperature of steam at engines	192° C. (377.6° F.)	238° C. (460° F.)
Revolutions	88.19	88.47
I.H.P.	6,585.	6,750
Speed	16.60 knots.	16.95

(or a gain of 0.35 knot in favor of S. S. *Pérou*.)

Shipbuilders and shipowners may well turn their attention to this question, as it is likely to remove the only remaining objections to the general use of steam turbines for ocean navigation—a hope which is likely to be fufilled at no distant date.

VANADIUM IN CAST IRON.

An interesting investigation has been made by Mr. Moldenke, secretary of the American Foundry Association, regarding the possibilities of vanadium used in cast iron. Its

effects upon steel indicate its advantages when used in cast iron for railway car wheels, rolls, alkali pots, pump parts, etc.—in fact, wherever stresses are heavy and repeated, and where castings are subjected to shocks or great variations in temperature. A ferro-vanadium carrying high carbon was selected because it melted at a lower temperature and would also be cheaper for the foundryman. Varying proportions were added to the ladle of molten metal, first in lump form. As this did not give satisfaction with the small quantities of iron used at a time, the alloy was powdered before using. As vanadium, besides being a great strengthener, is also a powerful deoxidizing agent, and as the increase in strength obtained by its use might be attributed to the purification of the iron only, a further series of tests was included in which the ladle was first treated with 80 per cent. ferro-manganese in sufficient quantity to add 0.5 per cent. of manganese, and then the ferro-vanadium. In order to throw some light on the deoxidizing power of vanadium a set of tests was also made with burnt metal. All the tests indicate the value of the vanadium addition. The alloy used contained 14.67 per cent. of vanadium, 6.36 per cent. of carbon and 0.18 per cent. of silicon. While the vanadium content is comparatively low, this is a good alloy for foundry purposes, as cast iron is already high in carbon, and the silicon is too small to play an appreciable part in the results. While the attempt was made to get as nearly 0.05, 0.10 and 0.15 vanadium into the ladles of metal as possible, the analyses show that as much as two or three times this quantity remained after casting. This is due to the impossibility of accurately weighing out in the small space of time available to prevent undue cooling of the metal, when generally dealing with less metal in the ladle than had been expected or arranged for. Then, with the small quantities tried, the chances of irregular distribution were very great. A foundry with 5 or 10-ton ladles would give a better opportunity. Finally, there is the uncertainty of how much or little vanadium is oxidized. The very best results with both manganese and vanadium show

very little of the latter remaining. The results, however, are sufficient strongly to recommend the new alloy. A still better method would be to use a more powerful deoxidizer than manganese and add the vanadium on the top of it. A method which increases the breaking strength of a test bar from 2,000 pounds up to 2,500 pounds for gray iron, and 1,500 pounds up to 3,900 pounds for white iron, is sufficient to warrant further investigation on the part of every foundryman who has special problems in strength to master. It is expected to continue the investigations, making provision to keep the ladle with melted iron heated up for a fairly long period, so that better mixing of the alloy may result, and hence more accurate results can be obtained.

STEAM-ELECTRIC MARINE PROPULSION.

A paper, by Mr. William P. Durtnall, entitled, "The Generation and Electrical Transmission of Power for Marine Propulsion and Speed Regulation," was read before the Institute of Marine Engineers. Leading up through the stages of development in reciprocating engines to the adoption of steam turbines in ship propulsion, the author pointed out the few but important disadvantages involved in the direct-coupled turbine. It was necessarily designed to run at very low speed to permit the use of a propeller of high propulsive efficiency, and consequently its diameter and weight were increased to a very great extent. The blade clearance was also greater, to allow for expansion and contraction, involving higher consumption and leakage of steam. There was also the difficulty of reversing, and the increased consumption per horsepower when working below full load and speed. Tests on the *Lusitania* had shown an increase in consumption from 14.46 pounds to 26.53 pounds of steam per shaft horsepower per hour when speed was reduced from 25.4 to 15.77 knots. The ability to maneuver was of little importance with ships making long runs, but very important in short-voyage vessels and ships of war, in which

frequent starting and stopping and maneuvering in and out of harbor or in squadrons was necessary. To meet these requirements, astern turbines, of about one-third the total ahead power, and coupled to separate propeller shafts, were carried. The dead weight was therefore only partially utilized.

Full-power speed at reverse was only possible with a complete duplication of turbines, but the safety thereby secured was possibly of more importance in short-trip vessels than the increased weight involved. In order, therefore, to secure the complete success of the steam turbine for ship propulsion, means would have to be devised to allow the turbine to run at high speed and the propellers at comparatively low speed, so securing economy in both cases, and also to provide reverse motion for all shafts. After alluding to mechanical, hydraulic and compressed-air devices which had been tried and found inefficient, the method of electrical power transmission was stated to be that in which the greatest possibilities lay. This system supplied the very elements required to take advantage of high-speed turbines, saving weight and securing high economy in steam, by utilizing these to drive electric-power generators, the current so generated being used to drive low-speed motors coupled to moderate-speed large-bladed propellers of high efficiency. This method of transmission would do away with the necessity of extra turbines, shafts and propellers for reversing. The turbine generator would always run in one direction as regards speed rotation, while the motor could be reversed and efficiently run in either direction. Moreover, the direction of rotation and speed could be instantly changed to meet all conditions in practice, and this very important feature could be utilized with the utmost economy even at the lowest speeds and powers. The electric motor, as well as the turbine and generator, had also the capability of standing very severe overloads for short periods without damage. The large power conductors need only be broken under no voltage conditions, and the control could be operated from the bridge where of advantage.

The author was of opinion that for marine propulsion elec-

trical power transmission could only be successfully effected by polyphase alternating currents, with synchronous generators and squirrel-cage induction motors, on account of the low cost and weight per horsepower, absence of commutators, and high efficiency of these machines. In generators of this type the armature was a stationary closed ring with the winding embedded in slots round the inner face, inside which the field magnet revolved. The main current was generated in the stationary ring and taken off direct without any of the intermediary devices necessary when collecting current from a rotating source. The field magnet received its exciting current from a small direct-current machine mounted on the generator shaft. This current, which only amounted to about 2 per cent. of the generator output, was delivered to the revolving field through simple collecting rings. It was of importance to note the exceptionally high efficiency, light weight and low steam consumption of such combinations as converters of mechanical into electrical energy. The efficiency varied from 85 per cent. in small sets to 98 per cent. in large sizes, such as used for traction generating stations; the weight was between 35 pounds and 22 pounds per kilowatt output continuous rating, according to speed and other circumstances; while the steam consumption in 7,500-kilowatt sizes, running at 750 revolutions per minute, with 160-pound steam pressure at the stop valve, 150 degrees superheat, and exhausting into 27½-inch vacuum, was only 13.5 pounds to 14 pounds per kilowatt hour, including steam used for auxiliaries.

As regards the induction motor, its powerful starting torque, light weight, simplicity, low cost of construction, mechanical strength, durability and running characteristics, made it especially suitable for marine work. As there was no commutator and no sparking limit the output could be carried much higher per unit weight than in other machines. These motors could be built for marine work of from 1,000 to 10,000 horsepower continuous rating, weighing 35 pounds to 20 pounds per brake horsepower, with an efficiency of 93 to

97 per cent. Although polyphase motors were termed non-synchronous they always tended towards synchronism, and with squirrel-cage rotors the variation in speed from light to full load seldom exceeded 5 per cent., even in small sizes, and would probably not exceed 1 per cent. in large sizes. The main working current passed through the stationary part of the motor only, facilitating strong and reliable construction for the conductors and rendering the machine so simple as to require no skilled and very little unskilled attention with consequent low cost of maintenance.

Assuming a vessel of 4,000 horsepower fitted for electric propulsion with four propellers taking 1,000 horsepower each at 250 revolutions per minute, the motors would be polyphase induction type with squirrel-cage rotors and with stators wound for full, half and quarter speeds. The generating plant would comprise duplicate sets of turbo-alternators and exciters capable together of supplying 3,250 kilowatts, and running at 1,500 revolutions per minute, with 150 pounds steam pressure and 150 degrees Fahrenheit superheat. These alternators would be two-pole machines, and the motors would be wound for 12 poles giving a reduction of 6 to 1. For half speed a second winding would be arranged for 24 poles, giving 12 to 1 reduction with two sets of windings in parallel, and for quarter speed this winding would be arranged for 48 poles, giving 24 to 1 reduction; the synchronous speeds would thus be 250 revolutions per minute for full speed, 125 revolutions per minute for half speed, and 62½ revolutions per minute for quarter speed.

At full speed of the vessel the propellers would require 4,000 shaft horsepower, and the turbo-generators would be run in parallel delivering 3,250 kilowatts to the motors. The consumption of steam would be 13 pounds per shaft horsepower or 16 pounds per kilowatt hour, equivalent to a total consumption of 52,000 pounds of steam per hour. Compared with propeller turbines the consumption in which, under similar conditions and speed, was of the order of 22 pounds of steam per shaft horsepower or a total of 88,000 pounds per

hour for 4,000 horsepower, the saving in favor of electric transmission was no less than 41 per cent. At half speed of the vessel about 600 shaft horsepower would be required, less than half load on one turbo-generator, and this would allow the duplicate set to be shut down. Estimating the motors at 60 per cent. efficiency on half speed, the generator would deliver 740 kilowatts at its full normal speed, and take 24 pounds of steam per kilowatt hour, equivalent to 17,760 pounds per hour, as against 28,200 pounds for propeller turbines, thus saving at least 37 per cent. in steam when the vessel is moving at half speed. The weights of the electrical transmission plant in this example would be—

4,000 B.H.P. at 35 pounds per H.P. developed......................say	62½ tons.
Conductors, switch gear, &c...	6
Two turbo-generators as above...	70
Condenser for above..	19
Steam piping, &c...	13
Air pump and motor...	6
Circulating pump and motor..	7½
	184

While the weight of the direct-coupled turbines and part of the propeller shafts, tunnels, &c., including condenser, steam pipes, &c., air and circulating pumps—which would have to be arranged efficiently to deal with the 88,000 pounds of steam—would be, at least, taking the speed of the turbines at 250 revolutions per minute, 148 tons, showing that the electrical machinery would be about 25 per cent. heavier, but it is here necessary to point out that that only applies to the plant from stop-valve to propeller-shaft connections.

This comparison does not cover the saving in power and weight of boilers. On the other side of the stop valve the weight of cylindrical boilers (empty), mountings, funnel, forced-draft gear, pipe work for steam-water and exhaust, pumps, gratings, platforms, &c., is stated to be 180 pounds per indicated horsepower in reciprocating-engined ships. Taking a vessel carrying two reciprocating condensing engines developing together 4,000 brake horsepower—equal to

4,700 indicated horsepower at 85 per cent. mechanical efficiency—the weight of boiler and stokehold equipment would be 377 tons. At 16 pounds of steam per indicated horsepower, including auxiliaries and losses, the total consumption would be 75,200 pounds, or 200 pounds of steam per hour per ton of boiler-room equipment.

At this rate the boiler-room equipment on the electrically-equipped vessel, taking 52,000 pounds of steam, would be 260 tons, while for the propeller-turbined vessel the weight would be no less than 440 tons. There would thus be saving for equal propeller horsepower of 180 tons weight—that is, no less than 40 per cent. Comparing coal consumption, the author took it that, with good Welsh coal, hot feed and clean flues, it was possible to evaporate 10 pounds of water per pound of coal burnt, and at this rate a turbine-propeller vessel would burn 8,800 pounds per hour, as against 5,200 pounds by the electric-propeller vessel—a saving of 1.6 tons per hour. This represents a saving in dead weight carried of about 230 tons on a six-days' trip, with correspondingly reduced running cost.

Electrical propulsion should be of considerable interest to cargo-vessel owners, as not only could dead weight and cost be saved, but the propeller speed could be kept as low as necessary and usual in these slow boats to secure the best economy at the propeller; and it would also be possible further to reduce the propeller speed if necessary to meet practical conditions by slight increase in the weight of the motors only, the generating-plant weight remaining the same. The author pointed out that the conclusions deduced should not be considered as perfectly definite on account of the widely different conditions in practice, but the paper was chiefly put forward to lead naval architects and marine engineers to give serious consideration to the question of electric propulsion.

Reference was made to other systems proposed and a large number of lantern views and drawings exhibited. The original Hart-Durtnall continuous-current system employed series-wound generators and motors direct-coupled to six propeller

shafts, but was for small powers only. In Mr. Parsons' system the exhaust was taken from the main reciprocating engines to drive a low-pressure turbine coupled to an electric generator delivering current to a motor on the engine propeller shaft. Single-phase commutator motors had been proposed in one German and one American system; in the former case with three-phase and in the latter with single-phase generation, and in one other American proposition three-phase non-synchronous generation was included. A Swiss proposition was to use direct-coupled turbines at the vessel's full speed and a separate turbine driving an electric generator supplying current to electric motors on the main turbine shafts for reducing the vessel's speed or reversing. The reverse, however, in most of these systems was only one-third of full power. The Hart-Durtnall three-phase system, as applied to marine propulsion in conjunction with internal-combustion engines, providing a reverse and three ahead speeds with control from the bridge, was referred to, but the author pointed out that until a satisfactory internal-combustion engine of large power was produced, the steam turbine would remain the most simple, light and efficient prime mover. —"The Engineer."

SMOKELESS POWDERS.

Recent accidents have again called attention to the question of modern powders, and have once again afforded a proof that much anxiety is felt by the public in regard to these powders. The loss of the Japanese ship *Matsushima* has very generally, and without much hesitation, been attributed to a decomposition of cordite, although nothing definite is known as to the accident which led to the foundering of this ship. The explosion of the Chilian powder magazine at Batuco, in the latter end of March, was first assigned to the decomposition of French powders, which had been manufactured as far back as twenty years ago; later, however, it was discovered that the magazine contained powders of Ger-

man manufacture only; these powders were then assumed by the public to be the cause of the disaster without further inquiry.

The mere statement "decomposition," or "spontaneous combustion," of powder is both a simple and a very striking one; it cannot be said to define in any way the first cause of an explosion, but it has the curious effect of satisfying public opinion. To all thinking minds it nevertheless remains nothing but a mere statement, and it requires to be proved in each particular case. In a great number of instances, however, no attempt is made to demonstrate fully that such a statement really goes to the root of the matter.

There recently appeared in one of the best Paris daily papers an article which deals with the explosion on board the *Jena*. This article was evidently due to a technical expert, but it was written in the very discreet style which characterizes the paper and in such a way as not to contradict too openly as yet the opinion which generally obtains in regard to that explosion. It gives an explanation of the accident, and leads up to the opinion that the French "B" powder,* so generally condemned—and with many apparently good reasons, one must admit—should be exonerated in this particular case. There is, however, much that is indefinite in the article in question, because it gives only a fragmentary explanation of the cause of the disaster. It states that "* * * neither strict justice nor sound logic require us, in the case in question, to attribute the cause solely to our 'B' powders * * *." The natural conclusion that can be drawn from such a statement is that there are other explanations which better account for the occurrence, and which the French paper did not see its way clearly to publish. Such other explanations, we believe, can be gathered from the reports issued by the committees appointed by the French Parliament for investigating the causes of the disaster, which reports are criticised in very moderate terms in the article in question. It says, "* * * the publication of

* The "B" powder is the pure nitrocellulose powder used in France.

the reports issued by the committees was found to be surrounded with many difficulties. These reports put forward everything; all evidence whatsoever has been accepted without selection and without criticism, so much so that the door remains wide open to all interpretations, even to the most malignant."

We have had an opportunity of looking through the reports in question, and from these we gather the following conclusions, which, we feel confident, will not be taxed with any ill-will.

In the first place, a very striking feature of the said reports is the little weight attached to some of the evidence given. Thus, for instance, it was recorded that the aft powder magazines for the 4-inch guns, in which the explosion appears to have originated, were closed by padlocks of a most usual type, easy to open with almost any key of a size approaching the right one, or by means of a hook; the door could even be kicked open. Notwithstanding this, the reports give much significance to the statement that the magazines were locked when the explosion occurred, and proof is adduced to the effect that the keys were at the time in their right place in the commander's quarters. On the other hand, the captain of artillery, who had charge of inspecting the *Jena* after the explosion, has recorded that the most heteroclitic substances were found in the powder magazines—such as soap, paper and tobacco—adding that there might have been candles also, seeing that he found one in one of the forward magazines in which, fortunately, no explosion occurred. French naval officers state in regard to this that it is a custom on the part of the men to use the magazines as private storerooms; attempts have been made to stop the practice, but so far only with small success.

A colonel of artillery, who has under his charge the inspection of the ammunition of the fleet, stated that he saw once in the powder magazine of a ship a loaded cartridge case, fitted with a celluloid diaphragm on which a candle had been fixed—for lighting purposes, no doubt—by causing first the candle grease to run hot on the diaphragm.

The report to the Senate concludes from the above that "the fact that the magazines are used for hiding various objects illustrates a trait in naval life, but no proof can be deduced from this fact in regard to the explosion," and it sets aside, without any further investigation, the possibility of the disaster being due to an imprudent act. The report to the Chamber of Deputies, on the other hand, takes note of the possibility of imprudence, but shows a certain amount of reluctance in doing so. It states that spontaneous combustion of the "B" powder has not been proved, but lays very special stress on all points that would tend to confirm that spontaneous combustion did actually occur.

The testimony tendered by the colonel, and also by the captain of artillery above referred to, has thus been almost totally ignored, through fear, perhaps, of giving too much prominence to a deplorable practice on the part of the crews. The fact should not be lost sight of that dangerous practices are very possibly of common occurrence also in the land installations in which the powders are manufactured, for it is in human nature to forget danger when in constant contact with it.

It would appear quite clear, therefore, that the supposition of imprudent conduct on board the *Jena*, either in a black-powder ammunition hold or in one containing "B" powder, should not so summarily be dismissed. The possible consequences of an imprudence should, on the contrary, have been weighed in the light of the actual occurrence. By supposing an inconsiderate act to have been committed in a smokeless-powder hold, the result, as regards consequences, would be the same as that due to spontaneous ignition, for it is quite clear that, whether spontaneous or not, the inflammation of powders can only propagate in one and the same direction after a first ignition, when all charges are stored in the same way. The French journal sums up the occurrence very clearly; it states: "The characteristic feature of all the accidents, without exception, which have happened on board ship up to the disaster on the *Jena*, by reason of the inflam-

mation of "B" powder, is the slow and gradual development of combustion. There have always elapsed several minutes between the first appearance of flames and the arrival of assistance, and in no case has the first manifestation of the accident had any directly serious results. Men caught in the midst of the deflagration have been able to escape easily without getting seriously hurt. The experience was similar in the course of the test carried out by the Gavre Committee, at Lorient. This test was made with a view to ascertain what would happen in a powder magazine of the type of those of the *Jenà*, in which a charge was ignited in the midst of others. After the first ignition, followed by the projection of alternately increasing and decreasing flames and jets of gases, five minutes elapsed before the first explosion took place."

This characteristic feature does not appear to have received sufficient attention on the part of the examiners; it is not given prominence in their reports, though it is confirmed by many witnesses. When a similar accident occurred on board the *Forbin*, the officers hesitated for some time with regard to the place whence the first flames issued, and had, besides, to improvise a fire service, a new crew having only just come on board; notwithstanding the consequent delay, the flames were extinguished before any explosion occurred. In the case of the *Duperré*, again, the first signs of inflammation were noticed at 11·45 in a port magazine for the 13.3-inch guns; no shattering effects occurred, although the fire was not under control until 12·15, and all danger only disappeared as late as 12·35. The five minutes which elapsed in the case of the Gavre experiment above alluded to may evidently be taken as a minimum, seeing that artificial ignition was carried out at the base of a cartridge, the black priming powder being lighted first. There is no evidence to show that in an instance of accidental ignition, or in a case of decomposition, ignition always first takes place at that same part of a cartridge; the experiment, therefore, introduced again another assumption, and one corresponding to a most dangerous eventuality, but the

experiment afforded no proof whatever that the occurrence could take place spontaneously; combustion also developed slowly and progressively in this experiment.

The events on board the *Jena* were in no way progressive, as in the cases we refer to; they commenced by a shattering explosion, which killed a number of men on the spot. The whole of the evidence is practically unanimous on this point. Only one witness gave it to be understood that flames were seen for two or three minutes before the first explosion, and the greatest importance has been given to this single evidence, particularly in the report to the Senate. But, on the other hand, it should be remembered that sailors were near and above the holds at the time; the hoist hatchways from the magazines opened directly on the deck on which members of the crew were dismounting a 4-inch gun. It is therefore absolutely incredible, under such conditions, that flames could have been emitted during two or three minutes without an alarm having been given. The officers killed in their cabins were not simply suffocated; they were crushed to death by the explosion. All tends, therefore, to prove that a shattering explosion occurred without any warning whatever, and this is confirmed by Admiral Manceron, a survivor of the disaster.

It is difficult, therefore, to entertain the supposition that powder "B" became ignited, either spontaneously or by reason of an imprudence, for this supposition does not fit in with the facts ascertained in the case of the *Jena*, or with those in the case of other ships. In order to maintain this supposition it would be necessary to surmise still further—namely, that the "B" powder behaved in the case of the *Jena* in a new and unknown manner.

If, on the other hand, the possibility of an imprudence be considered, which led to the ignition of black powder in one of the magazines containing this latter powder, the accident becomes easily explicable without it being necessary to entertain any consecutive suppositions. Black powder always explodes with shattering effect, and in the case of the *Jena* this

would thoroughly explain why so many men were killed almost instantaneously. Ignition was propagated to the neighboring smokeless-powder magazines, then to the other black-powder magazine, this explaining how a witness, after having escaped the first explosion and placed himself out of further danger, could see flames issuing from the ship during two or three minutes.

As a conclusion, we think that the hypothesis of an imprudence committed in one of the black-powder magazines of the *Jena* is that which the best withstands impartial consideration, and we add that it might very well be that the French have depreciated more than they really had cause to do their smokeless powder. Following the disaster in the French ship, which we all deplore, our own Navy gave special attention to the matter of our cordites and their conservation; this is certainly a most excellent measure.—"Engineering."

FRENCH WARSHIP CONSTRUCTION.

It is no exaggeration to say that among the questions connected with naval architecture none has so great an importance as that which relates to the time occupied by the construction of ships. This statement forms the opening of a paper read by Mr. C. Ferrand, Ingénieur en Chef de la Marine, at the meeting of the Association Technique Maritime, held in Paris, on May 6 last, in which he compares the activity displayed in British and German naval yards with the dilatoriness that generally obtains in France. In pointing out the fact that France takes five years to build the ships which Germany can build in three years and England in two, Mr. Ferrand adds that the five years he mentions apply to the French Government yards; the private yards, when they are not hampered by Government red tapeism, can build quite as rapidly as the German yards.

In France the time reckoned for the construction of a ship counts from the date upon which the order for laying it down

is issued by the Admiralty to that of the entrance of the ship into actual service; in England and Germany the time counts from the actual laying down to the completion—that is to say, to the commencement of the trials. Now in France there is a long interval between the order and the actual laying of the keel, and an approximately equal interval is taken up by the trials. The author illustrated this by the following figures:

	Date of order.	Date of laying keel.	Interval.
République	June 28, 1901	Dec. 2, 1901	5 months
Démocratie	April 5, 1902	March 1, 1903	13 months
J. Michelet	April 5, 1902	June 1, 1904	26 months
Waldeck-Rousseau	July 31, 1905	June 16, 1906	11 months
Danton	May 8, 1906	April, 1908	23 months

	Commencement of preliminary trials.	Entrance into effective service.	Interval.
Charlemagne	April 2, 1898	Sept. 6, 1899	17 months
Suffren	Aug. 30, 1902	Feb. 5, 1904	18 months
Gambetta	Feb. 22, 1904	July 21, 1905	17 months
République	July 10, 1906	Jan. 1, 1907	5 months

The above indications would show, according to Mr. Ferrand, that when it is stated that France takes five years to build a ship, while England built the *Dreadnought* in one year only, the comparison is not a fair one, seeing that the *Dreadnought* was commenced in January, 1906, and completed in January, 1907; but the order for the ship was given before midsummer, 1905, and her trials took up more than half of 1907. Hence, by counting the time as it is counted in France, over twenty-four months, and not one year only, were occupied by the *Dreadnought*—a result which is sufficiently remarkable in itself and does not require any exaggeration. Hence, also, the comparison, five years taken by France, three years by Germany and two by England for building a battleship, given by the author of the paper.

	1906.	1907.	1908.	1909.	1910.	1911.
	£	£	£	£	£	£
Danton (building in Government yard)	66,612	209,602	356,864	526,059	539,400	234,400
Voltaire (building in private yard)	12,253	183,303	271,520	480,790	624,320	499,640

The financial question is at the root of the whole matter in regard to delay. An example of the distribution of expenditure, according to the budget of the present year, is given in the paper, in the table above.

If the French navy succeeded in building in three years the ships the order for which was given out on May 8, 1906, these ships would have to be paid on the budgets for 1906, 1907, 1908 and 1909; by dividing the cost over the four years instead of over the six the budget for the Navy would have to be increased by £960,000 in 1906, by £2,000,000 in 1907 and by £1,800,000 in 1908. This cannot be done, and the navy offices have to wait until 1909 and 1910 before there will be allotted to shipbuilding yearly payments of such amounts as will allow of really active work being carried out. Seeing that the regulations in regard to accounts require that the work effected in any one year must be paid out of the funds provided for that same year, it is necessary to proceed rapidly with the ships ordered in 1906 only during the years 1909 and 1910, at a time when they ought to be placed in active service. The situation is such that if the yards built quicker than is prescribed, effective measures would have to be taken to delay them. The Central Naval Offices in Paris, through lack of available funds, have been obliged on various occasions to restrict the activity of the yards; this, adds the author, is ancient history, but the fact, nevertheless, remains that the yards are compelled to proceed slowly, and this has favored, as it were, the numerous existing causes which make for delay.

As a remedy, the author would propose to include the construction of new ships in a special extraordinary budget, as is done in Germany, and when the construction of a new unit had been voted by Parliament, the necessary subsidies for completing it would run no risk of being declined by Parliament; the necessary funds would be considered as placed at the disposal of the Navy, which would then be able to utilize them to the best possible advantage. With the present practice, however, the Navy Department draws out programs in

which are provided amounts for forthcoming years much in excess of those for the year under immediate consideration; when the following years are reached, no further consideration is given to the provisions formerly drawn up. The aim of the Minister of Finance is that expenditure be maintained low; the difficulty is met by carrying the provisions forward by one year or two, and the result of this mode of operation is to delay more and more the fulfilment of a program.

In dealing with the manner in which the building of a ship should proceed, the author states the very evident fact that the drawings should be got out and the contracts for the material and machinery passed in a definite order corresponding to the rational progression of operations at the naval yard. Thus, if it takes twenty months to build the turrets, twenty-four months to build the engines, and twelve months to build the hull, it is clear that the engines should be put in hand first, then the turrets, and lastly the hull. The French navy does not proceed on these rational lines; it gives out the order for the hull first, then a long discussion is started on the type of turrets to be used, and these are ordered at a time when they ought to be completed. The same takes place in regard to to the boilers; a selection among the various types of boilers raises such an amount of discussion that the Secretary of State for the Navy postpones a decision and an order up to the last moment, hoping, probably, to bequeath to his successor in office the difficulties and the responsibility of a selection. The following dates speak for themselves:

	Democratie.	*E. Quinet.*
Date of order for the ship	April 5, 1902	Aug. 27, 1904
Date of laying the keel	March 1, 1903	Nov. 6, 1905
Date of contract for 12-inch turrets	Aug. 4, 1903	......
Date of contract for 7.66-inch turrets	July 13, 1904	July 16, 1907
Date of contract for boilers	June 6, 1904	Aug. 3, 1906

In this connection it should be borne in mind that the naval yards require to keep their *personnel* regularly employed, with the result that it becomes necessary at a given time to put in hand a fresh unit to occupy the labor which gradually

becomes available with the completion of a former unit. In order to meet this the Secretary of State would have at the right moment to take steps to obtain from Parliament the authorization for laying down a fresh unit, for which the necessary credits should be made available and the necessary plans completed. But the situation at the naval yards is never so met. The Navy, it is true, endeavors to approach Parliament in good time, but it is in Parliament that difficulties occur; thus the program for 1906 was voted at the commencement of the year, but was placed on the carpet again by a series of questions at the period when the orders were about to be given out, and this led the Secretary of State to obtain a fresh vote from Parliament before he finally signed the contracts.

The original outline drawings are discussed and altered under the varying influences of Parliament and the Navy, and up to the last moment schemes are dealt with, and not final data. Then arrives a day on which the Secretary for State gives out the order for laying down the unit; but this is done with the sole object of closing discussion and making it possible to start on the detail études and drawings. It is therefore a fallacy to date the actual commencement of a ship from that day. The order for the ship being given, the Admiralty immediately proceeds with the business reckoned as the most urgent, this being generally to distribute work to the naval yards, the workmen in which, through lack of orders, are on the point of standing with folded arms; hence the hull is put in hand much before the engines, boilers, turrets, &c. The work on the hull forms a most unsatisfactory operation, nothing being yet known as to the dimensions and the position of any of the essential parts of the ship. It is carried out without order or method, simply to occupy the men; and large portions of the ship are built which, it is well known, will have to be taken to pieces later on. Owing to alterations in the plans, several of the ships are designed twice over in course of construction, and there is not the least doubt, says the author, that should the French Admiralty, using the same

methods, entrust one of the largest British shipbuilding yards with the mere construction of a battleship of, say, the *Danton* class, its delivery would not take place sooner than if built in a French yard.

He explains at length the causes which make for delay; these can be summarized in a lack of proper understanding between the designing and managing departments and those in charge of execution. Red-tapeism, the interchanging of papers and visas for every trifling detail, also play a large part in causing delay. Thus, when a naval yard or a private shipbuilding firm raises a point of detail in the construction of a ship, the reply from the Ministry takes three months in the ordinary course; should discussions, however, be raised, the loss of time is increased to six months, and occasionally to one year. The differences of opinion entertained by the Ministers who succeed each other at the head of the Navy have also been the cause of serious delay in the increase in number of French fighting units. It occurs also that orders for fresh units are given out at a time when the men are fully occupied with work on hand. This method of proceeding, says Mr. Ferrand, is preferable to that referred to above, but it has the disadvantage of increasing the nominal time taken for construction.

Interesting dates are given to illustrate the delay experienced in the case of various ships of recent construction, and the very surprising statement is made that when a Government yard has received from the Ministry the order for laying down a unit, the yard has to ask the Ministry to sanction the purchase of the required plates for that same unit.

The author also reviewed the situation as regards private companies. Whereas it takes a fortnight in England to obtain plates and sections, it takes in France three or four months. The French works require six to eight months to supply steel castings of simple shape; a sternpost cannot be delivered under a year. Such unfavorable conditions are partly explained by the hesitancy and absence of method which rule in the Ministry of Marine. If the latter had defi-

nite programs, and worked up to them, the industrial concerns of the country would be less timorous; they would, if need be, increase their means of production, with a view to manufacture in larger quantities and more rapidly.

The inspection of the material in course of manufacture is another cause for delay. It is essential, of course, that material of first quality only should be used in ship construction, but now that the manufacture of steel has reached such a high degree of perfection, and that the heroic ages are past, is it necessary, asks the author of the paper, that active means should be taken to prevent the putting in place of a plate or a rivet when the manufacture of the metal used for these has not been witnessed by the naval inspector? Time is also lost in armor-plate tests. When a plate for testing is selected from a lot, a suitable backing, similar to the ship's side, has to be built up, and several months are spent in correspondence, work and tests for each separate plate. The Government engineers, moreover, do not concern themselves sufficiently with setting out simple shapes, easy to manufacture, and very often the armor plates, in particular, are designed in total unmindfulness of the difficulty of execution.

The trials of ships also take up too much time; the trials of all the numerous auxiliary engines are often very laborious. For the latter class of engines, competition has been carried to excess, with a view, perhaps, to save £4,000 first cost on a ship of £2,000,000; this saving is more than compensated for by more lengthy trials and difficulties in actual service. The time taken by the trials is further increased by the practice, now very general, of ordering from different builders the boilers, the engines and other main apparatus, all of which require independent tests.

Some of the remedies advocated are stated in the foregoing. The paper concludes by detailing them; they are, briefly, decentralization in some departments, centralization in others, giving the right persons the required authority, and less red tape. No far-reaching reforms are necessary, says the author, but only measures of detail, such as a minister can obtain by a decree.

Considering the decrease in the number of men employed in the naval yards, the reduction of the working hours to eight and the state of mind of the men, the author very greatly questions whether the 18,000-ton battleships now in progress will be completed in the four years originally stipulated. —"Engineering."

NEW BRAZILIAN BATTLESHIPS AND THEIR ARMOR.

The admirable reliability of modern armor, as manufactured on the Krupp cemented process, has had no more convincing demonstration than that published on page 825. The plate, after an attack equal to 2,900 foot-tons per ton of plate, showed at the four points of impact a penetration of the surface for a depth of only about 2½ inches from the face. This plate is part of the armor manufactured at the Openshaw Works, at Manchester, of Sir W. G. Armstrong, Whitworth & Co., Limited, for the Brazilian battleship *Minas Geraes* and others now in course of construction at the Elswick Works of the firm and at Messrs. Vickers Sons & Maxim, Limited, Barrow-in-Furness, and the result achieved in resistance is consonant with the general excellence in all qualities of design anticipated in these ships.

Much has been said regarding these battleships, and before dealing with the details of the armor-plate trials some particulars of the vessels may be given. Three such vessels have been ordered—two from the Elswick Works and one from the Naval Construction Works of Messrs. Vickers Sons & Maxim, Limited, where also the machinery of all three will be constructed. The vessels belong to what is known as the "*Dreadnought*" era, but mark a decided advance in respect of gun-power of the vessels hitherto ordered, as, instead of having ten 12-inch guns, these new ships mount twelve such weapons, and all are of 50 calibers in length. Moreover, while the *Dreadnought* can bring only eight guns to bear on either broadside, the Brazilian ships can train all of the twelve guns on either broadside. This great advantage has been

achieved by a difference in the disposition of the guns. In the waist of the ship are two twin-gun barbettes, one on the port and the other on the starboard side, but arranged *en echelon*, so that the guns can be used on either broadside. Forward and aft there are the usual center-line barbettes, and behind each of these centrally-situated barbettes there is a second, in which the guns are arranged at a higher level, and sufficiently to the rear to enable them to fire over the weapons in the barbette in front without any probability of interference from flash. Thus it is possible to fire eight guns ahead, eight guns astern and twelve on either broadside; and as the guns are of exceptional power separately, the result is to make these Brazilian ships of immense offensive power. The vessels are to displace 19,250 tons. Reciprocating engines are being adopted for at least the first two of the ships, and, as regards the third, it has not yet been decided as to whether turbines will be preferred. The speed is to be 21 knots.

The armor protection of the ships is admirably arranged, and the side plating will extend from bow to stern. The greater part will be armor weighing 360 pounds per square foot, and for the *Minas Geraes* this armor has been constructed at the Openshaw Works. It was prescribed in the contract that a plate should be selected by Admiral Duarte Huet de Bacellar, President of the Commission of the Brazilian navy, and a recognized authority on ballistics, who has been closely associated with the construction of the new vessels. The plate thus selected was mounted in a cell at the company's proving ground at Ridsdale. The backing consisted of 2-foot oak balks, laid in two layers transversely to each other, with a skin plating at the rear, so as to represent as far as possible the actual condition on the ship. The plate, with its backing, was secured by ten bolts, while to the rear there were heavy stop plates, as is usual. The trials took place on July 21.

It was specified that the attack should be by a 9.2-inch 40-caliber gun, using 380-pound projectiles made by Messrs.

Thomas Firth & Sons, Limited, of Sheffield, according to the British standard service pattern, and that the charge should be such as to give a striking velocity of not less than 1,850 feet per second, and as close an approximation to 1,900 feet as is possible, the range being 277 feet.

The results are set out in the annexed table, recording the ballistics for each round.

RESULTS OF TESTS OF 300-POUND K. C. ARMOR PLATE FOR THE BRAZILIAN BATTLESHIP *MINAS GERAES.*

No. of round.	Nature of projectile and weight.		Charge.		Striking velocity.	Energy.	Remarks.
	Armor-piercing shot.		Cordite.				
	lbs.	*oz.*	*lbs.*	*oz.*	*foot-secs.*	*foot-tons.*	
1 *a*	381	8	55	4	1,895	9,497	No cracks developed.
2 *b*	380	12	53	12	1,877	9,288	No cracks developed.
3 *c*	381	12	53	12	1,872	9,273	No cracks developed.
4 *d*	380	8	58	12	1,977	10,312	Fired to measure further resistance of plate; no cracking resulted.

a Shot broke up; caused very slight penetration; point remained embedded until third round.
b Similar result to round 1.
c Similar result to round 1. Point of round 2 shaken out.
d Similar to round 3, with slightly increased penetration.

The plate was accepted as result of first three rounds.

The first round resulted in the development of a striking energy of 9,497 foot-tons, and the projectile, which weighed 381 pounds 8 ounces, was broken up, the point alone remaining embedded to a very slight extent; but when the third round was fired this point fell out, and it was subsequently recovered, very much abraded. The second round was, so far as its results are concerned, an exact repetition of the first, the penetration of the point being again about 2 inches. The third round, which struck the lower central part of the plate, had the effect of releasing the points of the first and second shots. The plate was then officially accepted as complying with all the conditions of the contract. The splinters from around the points of impact were very thin and had a razor-like hardness. In no case was the penetration more than 2½

inches, and there was no evidence of cracking. The back of the plate was, on later examination, found to show no breakage of surface.

The condition of the plate suggested the idea of firing an extra round with a larger charge, increasing the velocity by nearly 100 feet per second to 1,977 feet, and the energy developed to 10,312 foot-tons. The result proved very satisfactory. There was only slightly increased penetration, and, notwithstanding the close proximity of the point of impact to that of previous rounds, there was little splintering and no cracking. It was obvious that the plate could have withstood an attack with a striking velocity of fully 2,000 feet per second in the case of all three specified rounds. The heads of the projectiles Nos. 3 and 4 remained embedded in the plate, while the small pits left by the points which were shaken out from Nos. 1 and 2 shots show the limited extent of penetration.

The results, as we have said, are very interesting and indicative of the great progress made in the efficiency of armor. In this case it will be noted that the bore of the gun slightly exceeded the thickness of the plate, so that the test was rather more severe than usual. We are the more pleased at being able to give these results in view of the modern tendency towards secrecy in such matters.—"Engineering."

TORPEDO AND ANTI-TORPEDO ARMAMENT.

In a reply to a parliamentary question as to whether it was proposed to replace the 12-pounder guns in H. M. S. *Dreadnought* by weapons of larger caliber, the Secretary of the Admiralty states that the 12-pounder is "not considered inadequate" as a protection against torpedo attack. We may smile at so ingenious a reply, which in a given number of words gives the minimum of information and at the same time evades the question; but while we smile we may at the same time ask what is adequate protection against torpedo attack? We shall endeavor shortly to set out the main con-

siderations on which the answer depends. There has been for some time past a large proportion of naval opinion in favor of increased armament in destroyers, and in the later vessels of the *Tribal* class and in the *Swift* the 4-inch gun takes the place of the 12-pounder, which had hitherto been the largest size fitted. No doubt the difficulty of making the change earlier has been due to there being no modern Q.F. between the 12-pounder and the 4.7, and also to some extent from the consideration of stability involved by mounting heavier guns in the position which they occupy high above the water line in vessels of small beam.

It has been assumed by some that the change having been made in destroyers, it should apply equally to the anti-torpedo armament of the capital ship, and this, no doubt, is the assumption which prompted the question to which we referred at the beginning. Such an assumption, however, shows only a partial appreciation of the problem. The function of the destroyer is to catch and destroy the enemy's torpedo boats, and to make sure of its object it must have both speed and a suitable armament. For the latter, we may say that what is required is the equivalent of the man-stopping bullet. The torpedo boat which may conceivably be approaching within torpedo range of the battle fleet must be stopped and rendered useless at the earliest possible moment, consequently the harder and the fewer the hits which the destroyer requires to give to ensure this the better. On account of the greatly superior speed of the destroyer over the torpedo boat it is practically certain that such actions will be fought at close range, and a high muzzle velocity is not, therefore, essential in the gun carried by the destroyer, while the weight of the shell is of the utmost importance. Thus a short 4-inch gun with a comparatively low muzzle velocity, throwing a 25-pound shell, is very greatly to be preferred for a destroyer to the long 12-pounder.

But while it is the function of the destroyer to get to close quarters with the enemy's torpedo boat, it is the duty of the battleship to keep the torpedo boat, if possible, out of torpedo

range, and the anti-torpedo gun must therefore have a long range, that is, high muzzle velocity. Once the torpedo boat is sighted it becomes a question of time how soon it can be disabled, and as the range will generally be fairly long, it is obvious that the greater the number of guns which can be trained on the attacking boat, and the greater the rapidity of fire, the greater will be the chance of repelling the attack. Of course, the larger the gun the better for the purpose, provided that the essentials of number which can be trained on any one bearing, of muzzle velocity, and of rapidity of fire, are maintained. The 4-inch gun now being fitted in destroyers, which is comparatively short, does not comply with the range requirements, and it is obvious that if the muzzle velocity, which depends mainly upon the number of calibers in the length, is to be maintained, much greater space will be required for a 4-inch than for a 12-pounder. The main armament of a battleship is the first consideration, and the anti-torpedo armament must take up what space can be allotted for it after the main armament has been provided for, and it must also take such positions as will not interfere with the working at all angles of training of the heavy guns.

The *Dreadnought* mounts twenty-seven 12-pounders, and probably not more than ten of these could be trained on any one bearing, and if we consider the possibility of a single ship being attacked by several boats simultaneously, it will be realized that this number may not be more than adequate to prevent her being torpedoed. It is also possible that an equal number of suitable 4-inch could not be fitted without interfering with the main armament, either in the present *Dreadnought*, or by a rearrangement of the guns in a new design. In this connection it is interesting to note that the *Invincibles*, which are considerably longer than the *Dreadnought* and carry a smaller main armament, and which therefore have presumably considerably more space available for their anti-torpedo armament, are to carry sixteen 4-inch guns of a new pattern. Had it been possible efficiently to mount a greater number, no doubt the comparatively small addition to the

displacement would have been accepted. The advantages and disadvantages of a certain number of 12-pounders, or so many less 4-inch, have, no doubt, been fully weighed, but their lordships evidently intend to keep their opinion to themselves at present, and hence the delightfully turned phrase that the 12-pounder "is not considered inadequate."—"The Engineer."

SHIPS.

ARGENTINE.

The Argentine Government are making inquiries for new destroyers. Four ocean-going vessels of 650 tons and 27 knots, and eight of 450 tons and 30 knots, are projected. Inquiries have also been made for battleships of exceptional size.

Armored Gunboat Parana.—Recently Sir W. G. Armstrong, Whitworth & Co., Limited, launched from their Elswick shipyard the armored gunboat *Parana*, which is being built for the Argentine Government. In consequence of the shipwrights being on strike, the launching ways had been laid by apprentices under the direction of the foreman shipwright, and it is satisfactory to note that the vessel entered the water without any hitch whatever. Captain de Montes had charge of the construction of the ship.

From an interesting speech delivered by Sir Andrew Noble shortly after the launching ceremony, it appears that the *Parana* has a length over all of 250 feet; length between perpendiculars, 240 feet; breadth, molded, 22 feet 3 inches; depth, molded, 14 feet; mean draught, 7 feet 6 inches, and displacement about 1,000 tons. Her armament will include two 6-inch howitzers, six 3-inch, 50-caliber, Q. F. guns, four 75-millimeter, 12-caliber land guns, and eight rifle-caliber machine guns. The *Parana* and her sister ship, the *Rosario*, besides having powerful armaments, are well protected for vessels of their class, and, in addition to other protection, they will have an armor belt extending over the machinery spaces and magazines. It is believed that combining, as they do, such good offensive and defensive qualities, they will be the most powerful vessels of their kind in existence. The *Parana* is the fourth vessel the Elswick firm has constructed for the

Argentine navy, the first being the *25 de Mayo*, a cruiser of over 3,000 tons, the second and third being the *Nueve de Julio*, of 3,500 tons, and the cruiser *Buenos Ayres*, of 4,800 tons. In addition to these vessels, the allied firm of Ansaldo, Armstrong & Co. have during recent years constructed the armored cruisers *Garibaldi* and *Pueyrredon*, each having a displacement of about 6,750 tons. The armament for all these vessels was supplied from Elswick, and in addition, the firm has supplied the armament for other vessels of the Argentine navy, including the first-class cruisers *General Belgrano* and *General San Martin*. The *Parana* has been specially designed for river service. Her draught is small, and she will have good maneuvering power. Special arrangements have been made to guard against the extreme heat to which the gunboats will sometimes be exposed on the great rivers of the Argentine, and ample provision has been made for keeping the ship cool throughout, and especially with a view to maintaining a comfortable temperature in the magazines and machinery spaces.

AUSTRIA.

The Austrian Government is building a special type of scout of 3,500 tons and 26½ knots designed speed. The length is to be 425 feet and the beam 42 feet. The Stabilimento Technico, of Trieste, is responsible for hull and machinery, of which the latter includes turbines and sixteen Yarrow boilers.

AUSTRO-HUNGARY.

Two Shallow-draught Gunboats have been lately constructed to the order of the Austro-Hungarian Government by Messrs. Yarrow & Co., Limited, at their Poplar Works. They are intended for special river service on the Danube, and are being forwarded overland from Hamburg to Buda-Pesth. The dimensions are 60 feet in length by 9 feet beam. The hulls are of steel, galvanized, and all the vulnerable parts are protected by chrome-steel protection plating, proof

against the Lee-Metford rifle point blank at short range. The protection plating covers the entire machinery space, the revolving gun tower, the conning tower forward and the petrol tank at the stern. The petrol tank apparently forms part of the hull, but in reality it is quite a separate structure from the hull proper; so that in the event of this tank being damaged by shot or otherwise it is impossible for any of the petrol to find its way into the vessel.

The propelling machinery consists of five 70-brake-horse-power Yarrow-Napier four-cylinder petrol motors, arranged to drive three shafts. The two wing shafts are each driven by two sets of engines placed in tandem, having four cylinders to each set, *i. e.*, eight cylinders for each wing shaft, while the central shaft is driven by a single set of four cylinders. The dimensions of the cylinders are 6½ inches in diameter, with a 6-inch stroke. The reversing gear is in connection with the central single engine only. A special arrangement for inducing the circulation of air through the engine room is provided by means of a centrifugal fan, so as to avoid the possibility of any accumulation of explosive gases. The forward compartment is fitted up for the sleeping accommodation of two men, and the after compartment for that of four men, lockers, &c., being also provided. There is a mast and crow's nest fitted amidships, so as to secure a good range of vision over the high banks of the river, and a revolving gun tower will be placed aft, on which will be mounted a small gun. This gun tower is to be fitted in Austria by the authorities there.

Special arrangements have been made to prevent the vibration common to some of these fast lightly-constructed vessels, and in this respect the trial was considered by the Austrian authorities as a great success, as both vessels were found to be extraordinarily steady. Steering stations are provided in duplicate, one forward in the conning tower and one amidships.

The official trials of these two little vessels took place on the River Thames, over the Admiralty measured mile, on

June 22 and 23, the Austro-Hungarian Government being represented by Captain N. Von Wawel-Louis, Naval Attaché, Herr H. Wagner, Chief Constructor, Herr J. Seifridsberger, Chief Engineer, and Lieutenant Hoppe. The trials consisted of a continuous run of one hour, carrying a load of 3 tons, and the mean speed of the two vessels was found to be 22½ knots.

A subsequent trial took place, of one hour's duration, to test the radius of action, and it was found that at 11 knots the radius of action was at least three times as much as it would have been had the vessel been propelled by steam.

A special condition in connection with these vessels was the limit of draught, which, to the bottom of the screw, was 2 feet 8 inches.

These two gunboats are very similar to the one purchased two years ago by the British Admiralty, now called *Mercury II*, which attained, when light, a speed of between 25 and 26 knots. This little vessel has been in commission for the last two years, most successfully.—"Engineering."

BRAZIL.

Minas Geraes.—This very important vessel has been launched from the Elswick Shipyard of Sir W. G. Armstrong, Whitworth & Co., Limited, Newcastle-upon-Tyne. She is the first of three battleships recently ordered from the firm for the Brazilian navy and is by far the most important vessel that has ever flown the Brazilian flag. She has a greater displacement and a larger armament than any battleship hitherto launched in this country for our own or any other Navy.

For some years it has been the intention of the Brazilian Government to completely reorganize their Navy, which, as regards many of their ships, had become somewhat obsolete. The original scheme was to build three battleships of moderate dimensions, together with some armored cruisers, fast scouts and torpedo-boat destroyers, and Messrs. Armstrong were entrusted in a great measure with drawing up proposals for the whole scheme of reorganization. It was largely, no

doubt, owing to the experience obtained from the Russo-Japanese War, followed by the advent of our own *Dreadnought*, that it was finally decided by the Brazilian authorities, in consultation with the firm, to adopt a type of vessel combining a most powerful armament together with good armor protection and a high speed, all of them qualities which necessarily involve a vessel of very large displacement in order to embody such a combination. The *Minas Geraes* was, therefore, designed by Mr. J. R. Perrett, the head of the shipbuilding department of Elswick, to meet the Brazilian demands, which, in addition to the main features, involve many special requirements to suit the Brazilian service, the vessels of that Navy being throughout the greater part of the year in a tropical climate.

In view of the decision arrived at by the Brazilian Government to place the order for the construction of these three larger battleships, it was decided, for the present, not to build the armored cruisers proposed in the original scheme. There are, however, under construction at the Elswick Shipyard of the Armstrong Company two very fast scouts, of 3,000 tons displacement each.

The main features of the *Minas Geraes* are as follows, viz: Length 500 feet, breadth 83 feet, with a displacement approaching 19,500 tons on the normal draught of 25 feet. The guaranteed speed of the vessel is 21 knots, and the bunker capacity is 2,000 tons, which is sufficient to give a very large radius of action at a moderate speed. Oil fuel is arranged for in addition to coal.

The machinery and boilers of the *Minas Geraes*, and also of her sister ship building at Barrow-in-Furness, are being constructed by Messrs. Vickers Sons & Maxim, Limited. The engines are of the ordinary reciprocating type, this arrangement being considered most suitable for the Brazilian service.

The armor, which is being manufactured at Messrs. Armstrong, Whitworth & Co.'s works at Openshaw, Manchester, is of the Krupp cemented quality, with a main water-line

belt 9 inches in thickness, slightly tapered fore and aft. This belt is carried to the height of the upper deck over the citadel, thus affording complete protection to all the barbettes, machinery, boilers, magazines, etc.; and over the citadel the upper deck itself is thickened to form a protective deck, in addition to the protective deck proper, which runs all fore and aft in the usual manner.

The armament consists of twelve 12-inch guns twin mounted in six barbettes. Four of these barbettes are carried on the upper-deck level, one forward and one aft on the center line of the ship, and one amidships on each broadside. In addition, two barbettes are carried at a higher level on the center line, firing over the other two center-line barbettes, special arrangements being adopted to protect the latter when the upper guns are firing over them. This arrangement admits of eight 12-inch guns being fired ahead or astern, or ten 12-inch guns on either broadside at one time. The secondary armament consists of twenty-two 4.7-inch guns, fourteen of which are carried on the main deck behind the protection of the citadel armor, the other eight being carried in well-protected positions at a higher level. There are, in addition, some 3-pounders and smaller guns.

It is hardly necessary to add that the vessel will have a very complete outfit and equipment of every kind, similar to that of first-class battleships in our own and other navies; very special arrangements have been made for ventilating the ship throughout, and more particularly in the magazines and machinery spaces, for which special cooling apparatus has been provided.

This and the other vessels now building in Great Britian for the Brazilian navy, including the torpedo-boat destroyers which are in course of construction at the works of Messrs. Yarrow & Co., Glasgow, are all being constructed under the supervision of a Commission sent over by the Brazilian Government, the present very able Chief of this Commission being His Excellency Admiral Duarte Huet de Bacellar, who has the assistance of numerous Brazilian officers, who were present

at the launching. The vessel's launching weight was over 9,000 tons.

For those who are specially interested in the *Minas Geraes*, we may mention that a very fine model of her is to be seen in the exhibits of Messrs. Armstrong, Whitworth & Co., Limited, at present on view at the Franco-British Exhibition.—" Engineering."

BULGARIA.

Bulgarian Torpedo Boats.—Bulgaria owned, up to quite recently, one single warship, the *Nadiejda*, a small 715-ton cruiser, built in 1898 by the Chantiers et Ateliers de la Gironde, Bordeaux; the *Nadiejda*, besides undertaking cruising duties, serves also as a training ship. Her principal dimensions are as follow: Length, 70 m. (228 feet 8 inches); Breadth, 8.16 m. (26 feet 9 inches); Draught, 3.20 m. (10 feet 6 inches.) She is propelled by two 2,600-horsepower engines, supplied with steam by Lagrafel et d'Allest boilers; her speed is 18.5 knots. Her armament consists of two 100-millimeter (3.93-inch), two 65-millimeter (2.56-inch), and two 47-millimeter (1.85-inch), quick-firing guns, and two torpedo-launching tubes. Her officers are of French nationality, and, under their command, she passed through the Dardanelles as a steam yacht for the reigning Prince, in which capacity she is also frequently used.

In 1903 the Bulgarian Government decided to reorganize their military forces, and included in their program a scheme for defending their coasts on the Black Sea. This scheme provides for the construction of a flotilla of torpedo boats of 90 to 100 tons, running at 26 knots speed and having a large radius of action.

The situation of Bulgaria, from both a political and an economical standpoint, rendered the carrying out of the scheme somewhat difficult, for, owing to the Treaty of Berlin, the craft could not be delivered under steam through the Dardanelles, and the industrial resources of the country did not allow of the boats being built completely on the spot.

Owing, further, to the ice floes, which frequently close the port of Varna during part of the winter, provision had to be made to haul up the craft from the river when cold weather set in.

The Bulgarian Government invited tenders for the work and decided, in 1904 and 1906, to order two sets of three torpedo boats each from Messrs. Schneider & Co., whose designs best met the desiderata put forward. The program included the construction of the boats in France and the putting down of a re-erecting yard at the port of Varna, including a launching and hauling-up slip, with the necessary tracks, cradles, and mechanical apparatus for laying up the boats during the winter months.

The principal dimensions and main features of the boats are the following: Length, 38 m. (124 feet 8 inches); Breadth, 4.4 m. (14 feet 5 inches); depth of hold, 2.75 m. (9 feet); displacement, about 98 tons; power developed by the engines, 2,000 horsepower; corresponding speed, 26 knots; radius of action at 14 knots, 1,000 miles.

The armament of each boat consists of three 450-millimeter (17.71-inch) torpedo-launching tubes and three 47-millimeter (1.85-inch) quick-firing guns; the ammunition carried being three torpedoes and 390 rounds.

The steam for the engines is supplied by two water-tube boilers, protected by the coal carried in the side bunkers; this affords a protective thickness of 500 millimeters (19.6 inches), equal to an armor plating of 40 millimeters (1.57 inches) thick. As is well known, the attempts at providing torpedo boats with a protective plating have been abandoned, owing to the great increase in the weight of the hull that would ensue thereby, and all efforts made for improving this class of boat have since been towards increasing the speed and armament to a maximum and improving the habitability of the craft.

There are no hard-and-fast rules for designing a coast-defense torpedo boat, and those nations who have recourse to boats of this class for the protection of their coasts have

to take into account, in selecting a type, both their geographical situation and their general naval policy. From the above characteristic features of the Bulgarian boats these boats would appear to form strong craft having a powerful fighting value. Though of light construction, they are strongly built and seaworthy. In service the crew numbers 23 men, including the commander and chief officer.

As is very generally the case, the crew space is in the fore part and the officers' accommodation aft; the necessary measures in regard to coal, provisions and navigability have been taken for facilitating long cruises.

The two du Temple boilers are mounted in the center of the boat, in the same stokehold. Forced draft in closed stokeholds renders intense combustion at high speed possible. The boilers are designed for a pressure of 17 atmospheres (250 pounds per square inch); they have about 220 square meters (2,368 square feet) heating surface. The engine is triple-expansion, working three cranks, and is connected to a surface-condenser. The cylinders are 420, 600 and 900 millimeters (16.53 inches, 23.62 inches and 35.43 inches) in diameter, with a 500-millimeter (19.68-inch) stroke. The engine can easily run at a speed of 330 to 350 revolutions.

An electric generating set supplies current for lighting the boat throughout. An evaporator is provided for renewing the fresh-water supply. The conning tower, in front of the funnels, is equipped with the usual apparatus for the transmission of orders. The boat is fitted with two rudders, which enable turning at high speed round a short circle.

The 47-millimeter (1.85-inch) guns are mounted in sponsons near the conning tower, and have a wide firing field; they can easily aim forward, broadside and abaft the beam. The ammunition holds are quite close, and the guns can quickly be served. One of the torpedo-launching tubes is fitted in the bow; the two others form a double tube, aiming in opposite directions; they are mounted on a platform on deck, near the center of the boat.

The three first boats are afloat; the others are in course of construction at the Varna yard.

The launching of the boats every time they have to carry out a cruise, and their hauling up again, required the putting down of a steam-operated slipway. The site available between the south dyke and the entrance to the Dewna Canal did not allow of putting down the erecting yard opposite the site available for the slipway, neither could the boats be put afloat and hauled up again longitudinally. It was necessary, therefore, to provide for the transversal and longitudinal transport of each unit, from the erecting yard to the slip, and inversely, a difficult problem, seeing that the hulls of the boats are of light construction, and that all the operations have to be effected with the boats fully equipped.

All the elements forming the hulls, galvanized throughout, and delivered to Varna in riveted parts as far as was practicable in regard to transport, were put together on the spot in the ordinary way, on cradles. The stern post and propeller support were bored out when the hulls were fully riveted, with a view to ensure a perfect alignment for the propeller shaft; the engines and boilers were then put in place, and the internal accommodations made at the same time.

Each boat, when thus completed and painted, was launched sideways by means of the slip. This operation comprises two distinct phases—lateral transport in the yard and longitudinal transport to the slip.

Before the first phase, the wood cradle is replaced by a stiff metallic frame carried on rollers and provided with sliding-blocks of the required height. For the lateral transport, the total load, torpedo boat and frame, is coupled to a set of ten jacks, which disengage the sliding blocks and place the boat-carrying frame on the fixed track. The frame and boat are then hauled by means of fixed hand winches. When the three-rail track is reached the frame and boat are lowered by winches on four strong trucks, which are placed previously in the required position and secured by chocks. The transversal traveling gear is then dismounted, and winches fixed at each end of the central track are used to bring the frame and boat on the launching slip. The launching of the cradle and boat is gov-

erned by two steel cables, which are wound on two steam-driven drums. After thus covering a distance of about 27 meters (90 feet) down the slip, the boat commences to float, and frees itself of the cradle.

Hauling up is effected inversely: the boat places itself stem foremost over the cradle, and the uprights on the outside allow the position of the boat to be accurately adjusted.

All the operations are carried out smoothly and without shock. In order to secure a better mechanical efficiency the builders have mounted all movable parts on rollers; they have also given the girders forming the frame a certain degree of flexibility to meet eventual deformations in the various tracks.

The hauling up and dry-docking of a torpedo boat takes about 35 minutes.

The boats are completing their trial trips. The one first built made 27.72 knots on the measured mile, thus exceeding the contract speed by 1.72 nautical miles per hour.—"Engineering."

ENGLAND.

The Gladiator salvage has been a somewhat long and tedious operation, due mainly to the troublesome tides and unpropitious weather. However, the ship is "up" at the moment of writing and should before long now be seen in Portsmouth Harbor. No absolute decision about refitting her seems to have been arrived at. She is a type of vessel now quite obsolete as cruisers go; but for that very reason likely to be useful in a variety of ways. Obsolete ships can be risked where better ones cannot be.

British 33-knotters.—All the first five are now practically completed, and it remains to be seen how naval men will appreciate them. More comfortable and commodious than the older vessels they certainly are, but surely on 850 tons they might carry more than three 12-pounder guns and two 18-inch tubes. In fact, to fit 4-inch guns has already been proposed. Their present armament compares unfavorably with most foreign destroyers now being built, and it certainly seems that

at least two more 12-pounders could have been worked in. The original magazine spaces, however, are now required for oil fuel, and the ammunition supply is perhaps hardly as convenient as it used to be.

Destroyer Building " on spec." has often been attempted by firms specializing in this class of work, not always with the success achieved by Palmers, who had completed two vessels of 400 tons and fitted with turbine machinery, which have just been acquired by the Admiralty to replace the *Gala* and *Tiger*. They are very similar to the *Kangaroo*, but of greater power; and the speeds attained have been well over 31 knots.

H. M. SS. Agamemnon and Indomitable.—The new British battleship *Agamemnon*, built by William Beardmore & Co., Dalmuir, which passed through her speed and consumption trials satisfactorily several months ago, has since undergone "final touches" in the outfitting basin of her builders, and has left the Clyde for Portsmouth, manned by a working crew from the south of England, the results of which are, of course, now well known. But for alterations in the original designs, due to the rapid evolution in naval architecture and, of late especially, to modifications made in the cooling arrangements of the magazines, as the outcome of untoward experiences on board ships of other navies in connection with the deterioration in the quality of cordite, through excessive temperature, this warship, which was launched in June, 1906, a week later than the Cunard turbine *Lusitania*, would have left the Clyde months ago.

The *Agamemnon*, which was laid down in October, 1904, and is a sister ship to the *Lord Nelson*, has a length of 410 feet between perpendiculars, a beam of 79 feet 6 inches, and a mean draught of 27 feet, her displacement being 16,600 tons. Her boilers and machinery were supplied by R. & W. Hawthorn, Leslie & Co., Limited, the designed horsepower being 20,000 and the speed 18½ knots. There are two sets of four-cylinder, vertical, triple-expansion engines. The normal coal capacity is 900 tons, but a maximum of 2,500 tons can be carried, as well as 400 tons of oil fuel. There are

fifteen Babcock & Wilcox boilers. The armament consists of four 12-inch, ten 9.2-inch, fifteen 12-pounders, sixteen 3-pounders, six pompoms and two Maxim guns. There are four submerged 18-inch torpedo tubes on the broadsides, and one submerged tube of similar diameter astern. The armor is of the Krupp cemented type. There is a 12-inch belt amidships and a 4-inch belt at the ends. The barbettes are protected by 14-inch N.C. plate, and the turrets above these by 8-inch K.C. armor, the conning tower having 12-inch N.C. plate to protect it. Two of the 12-inch guns can fire ahead and two astern, the arc of fire being in each case 240 degrees. Four 9.2-inch guns can fire both ahead and astern, and on each broadside four 12-inch and five 9.2-inch can be fired.

The first-class armored cruiser—or as this class has been called the cruiser-battleship—*Indomitable*, launched from the Fairfield stocks last year, after having been docked for hull cleaning in April last, has successfully completed her two-fifths-power machinery trial, and being the first of the three vessels of the *Invincible* class to be completed, is arousing a considerable amount of interest; quite as much, in fact, as was taken in the mighty *Dreadnought.*

The *Indomitable*, as also the other two vessels of her class, the *Inflexible* and *Invincible*, has a displacement of some 17,250 tons. Her length is 530 feet, her beam 78½ feet and her draught 26 feet. She was laid down in March, 1906. Like her sister vessels, she is fitted with turbines of the Parsons type, and with a designed horsepower of 41,000; her contract speed is 25 knots. All the machinery of the three vessels is to be interchangeable throughout. She can carry a maximum quantity of 2,000 tons of coal, but her normal capacity is 1,000 tons. Provision has also been made for carrying oil fuel. Her armament consists of eight 12-inch and sixteen 4-inch guns, and she has three submerged torpedo tubes.

The magnificent run which H. M. S. *Indomitable* has just made has shown that the new battleship-cruiser is capable of speeds hitherto unattainable in any navy, with the ex-

ception of such craft as torpedo-boat destroyers. It is impossible to give precise particulars of a performance concerning which no official information has been supplied. Broadly stated, her passage from Quebec to this country was made in five and a half days, but the number of hours has not been made public, nor the rate at which she came down the St. Lawrence. All that can be said is that leaving Quebec early on Wednesday morning, the 29th ult., the *Indomitable* for the 719 miles down the St. Lawrence River had to steam at a comparatively low speed. At Belle Isle, on the Newfoundland coast, the race home commenced, and the run across the Atlantic was covered at an average speed, variously stated as 25.13 and 24.8 knots. For four hours a speed of 26.4 knots was attained. The great speed at which the cruiser has steamed across the ocean is made all the more remarkable by the fact that this vessel has not been stripped in order to allow her to make a record run. She carried the heavy guns of a *Dreadnought*, a thick coat of armor, her magazines full of ammunition, and all the rest of the equipment of a man of war ready for active service. Her cost was enormous, approaching close upon £2,000,000, and before the year is out another two of these vessels will have been added to the strength of the Navy. The *Indomitable* is 560 feet long on the water line, 78½ feet beam, and has a displacement of 17,250 tons. Her propelling machinery consists of Parsons turbines, capable of developing 41,000 horsepower. She is one of a new group of cruisers, mainly intended for the convoying of fast merchant steamers should war break out. It is stated that on the measured mile she attained a speed of 28 knots. But the official reticence concerning her performance is complete. Steam is supplied entirely by Babcock boilers, made in Glasgow. Probably the most interesting question which she has settled is her steaming range at full power. This may be taken at, in round numbers, 2,500 knots. Her bunkers hold 3,000 tons of coal; how much more she carried, or whether she carried any addition at all, has not been stated. She is, we believe, fitted

to burn oil fuel. We understand that she reached Cowes at 9·40 P. M. on Monday with empty bunkers. Now, it is not likely that her machinery used less than 15 pounds of steam per horse per hour. Even that figure stands for a very fine performance. If her boilers evaporated 10 pounds of water per pound of coal, we have 1½ pounds of coal per horse per hour, or, say, 60,000 pounds, or 27 tons per hour. If her actual steaming time was 132 hours, then she must have burned 3,564 tons on the trip. Two or three hours more or less will not make much difference. Some allowance may perhaps be made for the run down the St. Lawrence. If she had only 3,000 tons of coal to burn, then she must have been helped by oil fuel, or her turbines did not exert 40,000 horsepower. In the latter case the efficiency of the ship as a whole is remarkable. Her propellers must be admirable, and the form of the hull under water reflects the greatest credit on her designer. No doubt, in process of time, the facts of the case will leak out. It is not impossible that they may be published abroad first. From the purely scientific point of view, the performance of the ship is so full of interest, alike to the naval architect and the engineer, that it will be matter for much regret if the publication of the main features of the *Indomitable's* performance is withheld for any considerable time.—"The Engineer."

H. M. S. St. Vincent.—The *St. Vincent*, latest and greatest of the British *Dreadnoughts*, was laid down at Portsmouth on December 30th, and will be launched September 10, 1908. She is the eighth of our all-big-gun ships, including the three vessels of the *Invincible* class. Only the broadest facts about her construction have been made known, and whilst she resembles the prototype in general arrangement, she is larger in every respect and heavier. Her length is 530 feet, her beam 84 feet; she draws 27 feet of water, and displaces 19,250 tons. Her turbines will develop between 24,000 and 25,000 horsepower, and her speed will be about 21 knots. Her armament will resemble closely that of the *Dreadnought*, but the opinion that the 12-pounders of that ship were too

small to repel torpedo attack has been allowed to prevail, and she will carry a number of 4-inch guns. The first of three Brazilian *Dreadnoughts*, which also will be launched September 10th, is the Elswick idea of what an all-big-gun ship should be. Elswick has always favored big armaments, and the *Minas Geraes* carries twelve 12-inch guns to the *St. Vincent's* ten. But it is in the disposition of the armor that we may look in the Brazilian ship for some hint as to the arrangement in the British ship. It must, however, be borne in mind that carrying fewer big guns she is able to bear heavier armor, and in place of the Brazilian 9-inch belt she has a belt amidships 11 inches thick, which probably tapers off considerably fore and aft.

Leading Dimensions of British Battleships.—

......	*King Edward VII* class.	*Lord Nelson* class.	*Dreadnought* class.
Length B. P.........	425 ft.	410 ft.	490 ft.
Breadth, molded...	78 ft.	79 ft. 6 in.	82 ft.
Draught................	26 ft. 9 in.	27 ft.	27 ft.
Displacement........	16,350 tons	16,550 tons	18,600 tons
Speed, designed....	18½ knots	18 knots	21 knots
I.H.P., designed....	18,000	16,750	23,000
Coals, normal........	950 tons	900 tons	900 tons
Coals, bunkers, fuel	2,150 tons	2,200 tons	2,700 tons
Main armament.....	4 12-in. B. L.; 4 9.2-in. B. L.; 10 6-in. Q. F.	4 12-in. B. L.; 10 9.2-in. B. L.	10 12-in. B. L.
Secondary battery.	14 12-pdr. 12 cwt.; 16 3-pdr.; machine boat and field guns	24 12-pdr. 18 cwt.; 8 3-pdr.; machine boat and field guns.	16 4-in. Q. F.; machine boat and field guns.
Submerged torpedo tubes.	Four	Five	Three

The British 38-knot Destroyer Swift.—The question of warship speed has been occupying a good deal of attention lately, and general interest in the subject has been considerably quickened by the performance of the United States cruisers of the *Chester* class and of the British *Indomitable*. There have been many assertions made as to what ship is entitled to bear the distinction of being the fastest warship in

the world, and although such discussions have as a rule been confined to vessels of good sea-going and sea-keeping qualities, the question in its wider bearings has been answered very emphatically by the British special-type torpedo-boat destroyer *Swift*. On her preliminary trials this vessel maintained for some hours a speed of 38.3 knots, or nearly 45 miles an hour—higher by three knots than the best four-hour performance ever achieved; and by modifying the propellers it may be possible to get a higher speed out of her.

The *Swift* was laid down in October, 1906, at the works of Messrs. Cammell, Laird & Co. at Birkenhead, and was built to the designs of the builders, modified and improved by Sir Philip Watts, the director of British naval construction. Her displacement is exactly double that of the largest torpedo-boat destroyers previously built, namely, 1,800 tons; while her length of 345 feet falls short by only 36 inches of the length of the 10,300-ton United States battleship *Indiana*. Her beam is 34 feet 2 inches—slightly less than one-tenth of the length—and the mean draught is 10 feet 6 inches.

The *Swift* is, like all recent British ships, fitted with turbine engines on the Parsons principle, designed to develop the stupendous horsepower, for her size, of 30,000, and to give a speed of 36 knots. The turbines are in two compartments, and drive four shafts with one propeller on each. The furnaces are fitted for the burning of oil fuel only, the carrying capacity being 180 tons; and it is the subject of considerable comment that this is no greater than the quantity carried by the 800-ton 33-knot destroyers of the *Tartar* class, which immediately preceded her. The armament of the *Swift* is limited to four 4-inch (25-pounder) rapid-fire guns and two 18-inch torpedo tubes.

After her speed, the most remarkable feature of the *Swift* is her cost. This amounts, in the case of the hull and machinery, to $1,237,310 and to $14,150 for the armament, a total of $1,251,460. This is a huge price to pay for a vessel of only 1,800 tons and practically without any fighting power, and may be profitably compared with the figures given below for

typical cruisers and similar war vessels in the British and in the United States navies.

The greater part of the cost of the *Swift* is, of course, absorbed by her speed; and in this connection it may be interesting to note that if the *Indomitable* had been designed for 23 knots instead of 25, it is estimated that she would have cost $1,500,000 less than she actually did, and that if the *Dreadnought* had been designed for 18.5 knots instead of 21, she would have cost $2,150,000 less. Since Great Britain has four *Indomitables* and eight *Dreadnoughts* built, building or projected, the total saving would have been no less than $24,000,000—sufficient to build another three battleships.

It is not known whether the British Admiralty intend to repeat the *Swift*, but it is regarded as very improbable. At a time when it is so difficult to get money from the Government for purposes of national defense, it is likely that the Admiralty will find some more substantial way of spending money than in the creation of speeds which, however startling, have but a very limited military value.

Ships.	Type.	Displacement normal, tons.	Speed, nominal, knots.	Armament.	Cost.
Swift, (British)............	Destroyer	1,800	36	Four 4-in.	$1,251,460
Adventurer, (British).....	Scout	2,940	25	Ten 3-in.	1,142,130
Amethyst, (British)........	Cruiser.	3,000	23	Twelve 4-in.	1,142,130
Chester, (United States)..	Scout	3,750	26	{ Two 5-in. Six 3-in.	1,625,000*

* Exclusive of armament.

—"Scientific American."

FRANCE.

The French have lately been fairly busy demolishing some of their old ironclads. The old monitor *Tempête* has just been fired at by the Mediterranean Fleet. Exact details of the firing are not obtainable, but substantially the results

were as follows: (1) The superstructure was blown entirely to pieces. (2) The mast was grazed by a number of projectiles which eventually brought it down. (3) The port side was fired at and the unarmored parts absolutely "honeycombed—with hits" a series of neat little holes. The starboard side, the side away from the hits, was badly damaged by shells bursting after getting into the ship. This side seems to have burst most of the shells. (4) The armor was several times hit, but in no case penetrated. (5) The range was considerable—8,000 yards according to some accounts. (6) The captains of guns fired first and secured 16 hits out of 40 rounds. Their successors got an average of 13 hits out of 80 rounds.

The old battleship *Admiral Duperré* was fired at and sunk by the Toulon forts, but details were kept confidential, as special projectiles were employed.

GERMANY.

The New German Dreadnoughts.—The recent Admiralty return giving the armament of the new German *Dreadnoughts* led to much discussion about the way the details had been kept secret. As a matter of fact, their principal features had long been known in those circles which were interested in ascertaining them, together with much more which detracts in naval eyes from the paper attractions of twelve 11-inch and twelve 6.7-inch guns. At the ranges at which ships of the *Dreadnought* class were designed to fight, the energy in an 11-inch shot is relatively very much less than in the case of a 12-inch compared with the energy at the muzzle. At the ranges and for the purposes for which the secondary armament is considered to be required in the case of the *Dreadnought*, the greater rapidity of the fire from the 4-inch is much preferred to the slower 6.7-inch. Moreover, the *Nassau*, with her very congested engine rooms and triple screws, will have to exceed her designed speed if she is not to be at least 1½ knots slower than the *Dreadnought*. Still more, the *Temeraire* class are improved *Dreadnoughts*, while the *Nassaus*

are, strictly speaking, cotemporary with the *Dreadnought* herself.

According to "Le Yacht," the armaments of the German *Dreadnoughts* are as follows: *Nassau* type, twelve 11-inch, twelve 4.7-inch; *Ersatz Baden* type, fourteen 11-inch, twelve 6.7-inch or fourteen 4.7-inch; *Ersatz Beowulf*, twelve 12-inch, twelve 6.7-inch; and the displacements 18,000, 19,000 and 20,000 tons respectively.

The same authority gives the cruisers as follows: "*E*" (*Blucher*), ten 11-inch; "*F*," twelve 11-inch and some 4.7-inch; "*G*," ten 12-inch; the displacements being 15,000, 19,000 and 22,000 tons.

The orders for the twelve new German destroyers of the 1907–8 program were recently given out. As at present arranged they are to be of 600 tons displacement and about 13,000 horsepower. A speed of 30 knots is to be guaranteed, but more is hoped for in view of the performance of *G 137*. All will be turbine driven—four by Parsons turbines, four by Melms and Pfenniger, three by Curtis and one by Zoelly turbines.

ITALY.

New Destroyers.—The Ansaldo Company has laid down no less than six stock destroyers of about 350 tons and 6,000 indicated horsepower. The Italian navy has been building a large number of boats of this type recently, carrying four 12-pounder guns and three tubes, but is now reported to be considering boats of the ocean-going type, with speeds of 30 knots.

RUSSIA.

Trials of Armored Cruiser Rurik.—The *Rurik*, designated an armored cruiser, but in some respects more closely resembling a battleship, built by Messrs. Vickers Sons & Maxim, Limited, at their Naval Construction Works, Barrow-in-Furness, has concluded, with marked success, probably the most exhaustive series of trials yet specified for any warship, and will shortly leave this country for Russia, to be added to the

navy of his Imperial Majesty the Czar. The vessel, which embodies not only the great experience of the Vickers Company, but also the valuable suggestion of the Russian Admiralty as an outcome of the recent war, is in many respects as notable a departure from former practice in naval design as was the *Dreadnought*. Indeed, she is the antithesis of what has been termed "the paper ship." In the first place the *Rurik* has a very powerful armament, not only for service in the line of battle, but also for repelling torpedo-boat attack. All of the guns have a greater angle of elevation and depression than in previous ships, as well as a large arc of training, and all are operated by electrical mechanism. In the second place, the vessel is specially notable for the effective character of her defence, as she is armored practically from the keel to the upper deck. In the third place, she has a great reserve of boiler power, the heating surface provided being equal to 2.86 square feet per indicated horsepower at full speed, and, as will presently be explained, she was required to maintain full speed for three hours with only three-quarters of this boiler power, so that the full speed of 22 knots is more comparable with the speed attained, even in British practice, with only 75 per cent. of the boiler power. In the fourth place, the vessel carries a greater supply of ammunition than is usually provided, and was, by the wish of the Russian Commission, loaded down on her speed trials to a displacement exceeding by 300 tons the correct displacement. As a consequence of these circumstances, any comparison of the speed performance of the *Rurik* with the speed of other vessels less effectively designed for attack or defence must necessarily be qualified, regard being had to the general scheme to make the vessel as reliable as possible in all conditions of warfare. This view has animated the builders and the Russian Naval Commission, composed of between twenty and thirty officers of great theoretical and practical ability and experience. In testing every detail of mechanism in the ship, it was a condition that wherever even the slightest adjustment was necessary, the whole trial should be repeated after the adjustment was

made. It was not enough that all concerned might be satisfied that the result must be satisfactory on the principle that effects follow inevitably upon incontrovertible conditions. Everything was done rather to thoroughly establish reliability by proved results, and the *Rurik* is therefore a most important addition to the navy of the Czar.

The designed displacement of the ship was 15,200 tons on a draught of 26 feet, and the realized condition is well within these limits. The length between perpendiculars is 490 feet and the molded breadth 75 feet.

The *Rurik* has four 10-inch breech-loading guns, 50 calibers in length, twin-mounted in barbettes forward and aft on the center line. Each of these guns can be worked through 35 degrees of elevation and 5 degrees of depression, and the forward guns can be trained 45 degrees abaft the beam, and the after guns 45 degrees before the beam. There are also eight 8-inch breech-loading guns, also 50 calibers in length, twin mounted in barbettes on the quarters of the ship, with a correspondingly large range of fire to that of the larger guns. For repelling torpedo attack there are twenty 4.7-inch quick-firing guns, also of 50 calibers in length ; sixteen of these are placed within an armored battery in the center of the ship, separated from each other by traverses of specially-hardened armor. This battery, being on the upper deck, enables the secondary armament to be placed higher above the water line than usual ; it also incidentally adds very largely to the armored protection, as it is above, and additional to, the normal armored side of similar ships. Aft there are four 4.7-inch guns, and these are also within armor on the sides of the ship, while to counteract the effects of raking fire three armored bulkheads have been fitted ; this is quite a new feature in the protection of warships. There are twelve smaller quick-firing guns. Two 18-inch torpedo tubes, completely submerged, are placed forward. Each of the guns in the ship is capable of developing a much higher muzzle energy than weapons of the same caliber hitherto fitted, so that from all points of view the armament of the ship is very formidable.

The exhaustive character of the ordnance trials is indicated by the fact that one hundred rounds—full charges—were fired from one of each type of gun, these guns being similar to the ship's guns, and built specially for trial purposes. Following this, thirty rounds were fired from two of the 10-inch guns and two of the 8-inch guns, and fifteen from the other guns at various angles of elevation and depression, and on various bearings, in order to test the mountings of the respective guns. The separate items of the mechanism had formerly been subjected to many trials in order to ensure reliability, especially in view of the departures from earlier prac tice, due to the extensive application of electricity. In this the Russian naval authorities have shown commendable progress. The care bestowed on adjustment of the mountings resulted in the trials at sea being successful. The respective gun mountings were worked to give, when firing ten rounds, a rapidity of two rounds per minute from the 10-inch guns, of three rounds from the 8-inch guns, and of eight rounds from the 4.7-inch guns, while the 47-millimeter guns fired at the rate of between twenty and thirty rounds, and the Maxim gun at about five hundred rounds per minute.

In regard to the defensive qualities of the design, the vessel has a complete belt from end to end, extending to a considerable distance below the water line. It is, for the greater part of the length, 6 inches in thickness, tapering to 4 inches and 3 inches at the extreme ends of the hull. For protecting the 4.7-inch guns, the upper strake, for 200 feet of the length of the ship, is of 3-inch specially-hardened armor, manufactured, like all the other armor, at the Sheffield works of the Vickers Company, and subjected to careful tests at the Eskmeals range. The barbettes, which are within this central battery, are of much heavier armor, having 7½-inch walls, while the conning towers are of 8-inch armor. Another feature is the range-finding towers, of which there are two, extending for a considerable height above the upper deck, and constructed of 5-inch specially-hardened armor. These offer, independently of the mast, satisfactory observation stations for the determination of the range for gun fire.

There are protective decks of a combined thickness of 4 inches, arranged so as to secure as far as practicable that all high-explosive shells shall burst outside of the ship. The base of each of the three funnels is protected by armored casings. The whole of the machinery and magazines which are under the water line are surrounded by armored walls, which extend from the main deck, through the protective deck, to the bottom of the ship. This is in addition to the usual construction of double skin. Thus all the machinery and vital parts of the vessel are adequately protected by specially-hardened armor.

The machinery, as we have already stated, has been designed with less regard to economy of weight than to reliability under any adverse conditions. The boiler power is considerably in excess of that provided in former practice. There are twenty-eight water-tube boilers, and these are fitted for consuming coal or oil fuel. The propelling machinery consists of two sets of four-cylinder triple-expansion engines, carefully balanced to obviate vibration and to make the ship a steady gun platform. Each set of engines has one high, one intermediate, and two low-pressure cylinders, the power under easy steaming being 20,000 indicated horsepower, with the boilers working at a steam pressure of 285 pounds to the square inch, which is reduced to 250 pounds before entering the engines. A complete system of auxiliary machinery has been fitted, and special attention has been devoted to the pumping and drainage arrangements, which are the outcome of much thought on the part of the Russian Admiralty officials.

The steam trials were conducted under the supervision of a large Commission of experienced Russian officers, who, as we have already indicated, have been actuated with the one aim of ensuring that when the vessel goes into commission she shall be thoroughly efficient even in the hands of officers without experience of this particular ship. As a consequence, the trials have been more protracted than is usual in other services where the best reliable results are got after

what is known in engineering language as the grinding down of bearings during the first few months of commission. In other words, the *Rurik*, as a result of her trials, is now in the position of other vessels which have been several months in commission. Each of the requirements of the specification prepared by the Russian Admiralty has been fully satisfied, and a study of the official results which we are enabled to publish shows that this ship, notwithstanding the very important innovations to ensure increased strength in attack and defence, is capable of an exceptionally high speed in continuous steaming, and even with some of the boiler power out of action. Perhaps the most interesting features of these trials were those at full power. In the British service the maximum power of the machinery has to be maintained for eight hours. In the case of the *Rurik* this condition had to be kept up for ten hours, and, in addition, as we have already indicated, the vessel had to run for three hours at 21 knots with one-fourth of the boiler power entirely out of service.

Moreover, during the usual twenty-four-hours' completion trial, made immediately before the acceptance of the ship and after the opening out of the machinery, it was decided to run the machinery for ten hours at full power. In the British service this commissioning twenty-four-hours' trial very rarely includes more than one-hour's run at full power. The *Rurik* on this trial made a splendid performance, as the speed maintained for the ten hours was much more than that required by the contract. The results are given in column 6 of the annexed table. The mean indicated horsepower was 20,675, as compared with 19,700 horsepower guaranteed; the mean revolutions being 141.6, against the 135 required for 21 knots. It will thus be recognized that the revolutions, power and speed are in excess, but in correct proportion, indicating the accuracy of the design and the realization of the usual marginal allowance. Moreover, the engines did not vary more than one revolution per minute, and, with the exception of one reading, the hourly results ranged between 20,000 and 21,000 horsepower. The earlier ten-hours' trial, of which the

TABLE SHOWING RESULTS OF TRIALS OF THE *RURIK*.

1	2	3	4	5	6
......	Mean of 30 hours at 12 knots.	Mean of 30 hours at 19 knots.	Mean of 10 hours at 21 knots.	Mean of 3 hours at 21 knots with three-quarter boiler power.	Mean of 10 hours at full power during 24-hours' completion trial.
Steam pressure, pounds per sq. inch	196.0	261.0	269.0	273.0	280.0
Vacuum, inches	27.12	27.0	26 0	25.8	26.2
Revolutions per minute	75.6	123.85	138.48	138.3	141.6
Indicated horsepower	3,039	13,359	19,355	18,953	20,675
Number of boilers in use	8	21	28	21	28
Air pressure in stokeholds, inch	0.13	0.3	0.31	0.58	0.36

results are given in column 4 of the table, was equally satisfactory, and the three-hours' trial with three-fourths of the boiler power in use, the leading points of which are given in column 5 of the table of results, was still more remarkable.

The speed was determined during the trials as a consequence of several runs made over the measured mile at Skelmorlie, on the Clyde. The condition stipulated was that throughout the ten hours, and later throughout the three hours, the engines should keep up an average number of revolutions equaling or exceeding the number corresponding to 21 knots, as ascertained on the measured-mile trials, and this was easily accomplished. The *Rurik* also carried through two thirty-hour trials, one at about 19 knots and the other at about 12 knots. These trials were to determine the radius of action, and the results are given in the table.

Very careful data were collected by the Commission, not only as to coal consumption, but also as to water consumption, tanks being specially provided. An important condition in the contract had reference to stability, and the specified metacentric height was exceeded by about 10 per cent., with which result the Russian officers were highly pleased. Observation was also taken of the temperatures in various parts of the ship, &c. Maneuvering trials were also

carried out, and in this respect the ship was found to be very satisfactory. Indeed, from the first to the last, the Russian Commission put the ship through a series of tests of a most searching character, and the result establishes that the severe conditions of the contract have been fulfilled, and that the *Rurik* is from every standpoint a remarkable ship of the line.—" Engineering."

SPAIN.

The New Navy.—Tenders have already been submitted for the new Spanish Navy. The battleships are to be of about 15,000 tons, 19½ knots speed and about 425 feet long. Three destroyers of 360 tons and 28 knots, and twenty-four torpedo boats of 180 tons and 26 knots, as well as four small gunboats of about 1,000 tons, complete the proposed fleet. The large ships are to be built at Ferrol and the smaller vessels at Carthagena. Both dockyards are to be entirely renovated, and it is estimated that the work will occupy at least eight years.

OBITUARY.

CHARLES WHITESIDE RAE, REAR ADMIRAL, U. S. N.,
Chief of the Bureau of Steam Engineering.

Rear Admiral Charles Whiteside Rae, Engineer-in-Chief of the Navy and Chief of the Bureau of Steam Engineering, Navy Department, died at his home in Washington, D. C., the evening of May 13, 1908.

Rear Admiral Rae was born at Hartford, Ct., June 30, 1847. After a preliminary course of study at the Champlain Academy, New York, he entered Rensselaer Polytechnic Institute and was graduated with the Class of 1866. Being attracted towards a Naval life, he entered the Navy as an Acting Assistant Engineer on October 10, 1866. Together with a number of other Acting Assistant Engineers he was sent to the Naval Academy for a two years' course of instruction, and was graduated from that institution in 1868.

After some period of sea service we find him in charge of the work of establishing a line of levels across the Isthmus of Tehuantepec (1870), and shortly after that he was attached to the Nicaragua Canal Survey Expedition. After this he was detailed to the Naval Academy as an instructor for the class of Cadet Engineers, remaining on that duty for several years. He saw duty on the *Lancaster*, European and South Atlantic Stations, and on the *Atlanta*, of the North Atlantic Squadron.

Admiral Rae was detailed to the important duty of head of the Department of Steam Engineering at the Naval Academy in September, 1893, and remained on that duty until June, 1897. During the Spanish war he was Chief Engineer of the Battleship *Iowa*, and participated in the bombardment of San Juan, Porto Rico, in the battle of Santiago, and in

several minor actions off the coast of Cuba. For "eminent and conspicuous conduct" during the battle of Santiago he was advanced three numbers, and for distinguished service in the Cuban campaign he was awarded a medal of honor.

For about a year after the Spanish war Admiral Rae had charge of the installation of new machinery for Yerba Buena Naval Station, and was then detailed as Inspector of Machinery for the Navy at the works of the Newport News Shipbuilding and Dry Dock Co., leaving this latter duty for duty under the Bureau of Steam Engineering in Washington. On August 9, 1903, President Roosevelt appointed him Engineer-in-Chief of the Navy and Chief of the Bureau of Steam Engineering, with the rank of Rear Admiral, which position he filled up to the time of his death, having been reappointed by the President in 1907 for a second term of four years. In 1890 he married Miss Rebecca Gilman Dodge, of Washington, D. C., who survives him.

Rear Admiral Rae was a Vice President of the Society of Naval Architects and Marine Engineers, a past President of the American Society of Naval Engineers, a past President of the Washington Society of Engineers, a member of the National Geographic Society, and a member of several prominent clubs in New York City and in Washington. In 1906 he received the degree of Doctor of Science from the University of Pennsylvania.

In the death of Rear Admiral Rae the Navy has lost a capable and efficient officer; one who worked quietly and well, and whose influence will long be felt for good in the field of his chosen profession. By precept and by example Admiral Rae strove to place Naval Engineering on the high plane that its importance deserves. His own rise from the junior grades of engineering duty to the head of the Naval Bureau of Steam Engineering was a fitting reward for duty well done. Admiral Rae was a man of charming personality. Courteous and dignified in bearing, he attracted all with whom he came in contact and made friends even of those whose pet schemes he could not favor.

BOOKS RECEIVED.

Handbook For the Care and Operation of Naval Machinery. By Lieutenant H. C. Dinger, U. S. Navy. This excellent work consists of 295 pages, and is made up principally from a series of articles that appeared in the Journal of the American Society of Naval Engineers by this author.

It will serve to fill a demand for a concise and simple description for the care and operation of naval machinery on many points not largely treated of in standard works on marine engineering.

The information contained in the Handbook has been derived from the personal experience of the author, and from consultation with Engineer Officers in the Naval Service.

It consists of thirty-two chapters, with one hundred and twenty-four illustrations.

The book is divided into six parts, as follows:

Part 1. Operation of Naval Machinery;
2. Care and Overhaul of Main Plant;
3. Fittings and Auxiliaries;
4. Care and Preservation, Subdivision of Hull;
5. Special Auxiliary Engines;
6. Spare Parts and Tests.

The publishers are the D. Van Nostrand Company, 23 Murray and 27 Warren Streets, New York. The price is $2.00.

Hydraulics. By S. Dunkerley, Professor of Civil and Mechanical Engineering in the University of Manchester and Director of the Whitworth Laboratories. Volume II, treating of the Resistance and Propulsion of Ships, of this

work has been received. This work treats in an exhaustive manner the subject of resistance and the propulsion of ships.

It is divided into six chapters, as follows:

Chapter 1. Stream Lines;
2. Waves;
3. Resistance of Ships: Eddy, Skin and Wave-making Resistance;
4. Wave-making Resistance;
5. Trials on Full-sized Ships;
6. Theoretical Considerations Affecting the Propulsion of Ships.

The book is published by Longmans, Green and Company, of London, New York, Bombay and Calcutta. The price is $3.00 per volume.

ASSOCIATION NOTES.

At a special meeting of the Council, held August 31, 1908, Commander W. W. WHITE, U. S. N., Retired, was elected a Member of the Council to fill the vacancy caused by the transfer of Commander B. C. BRYAN, U. S. N., to the Navy Yard, Philadelphia, Pa.

U. S. S. "MONTANA."

JOURNAL

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U. S. ARMORED CRUISER *MONTANA*.

DESCRIPTION OF MACHINERY—OFFICIAL TRIAL.

BY WILLIAM RUSSELL WHITE, LIEUTENANT, U. S. NAVY, MEMBER.

The armored cruiser *Montana* is one of two sister ships (the other being the *North Carolina*) built by the Newport News Shipbuilding and Dry Dock Company of Newport News, Va. The contract for this vessel was signed June 3, 1905, the price being $3,575.000.00, which does not include the armor and armor bolts (exclusive of protective deck), ordnance and ordnance outfit and certain articles supplied by the Government. The contract time for completion was thirty-six months. Owing to various delays, for which the contractors were not responsible, this time was extended, and the ship was delivered July 10, 1908.

The main engines were required to develop twenty-three thousand indicated horsepower when working one hundred and twenty revolutions per minute with a steam pressure of two hundred and fifty pounds at the high-pressure cylinder.

The guaranteed speed of the ship was twenty-two knots per hour for four hours.

PRINCIPAL DIMENSIONS OF HULL.

Length on load-water line, feet	508
between perpendiculars, feet	502
over all, feet and inches	504-06
Breadth, molded, feet and inches	72-06
extreme to outside of plating, feet and inches	72-10½
Trial displacement, tons, about	14,500
draught to bottom of keel, feet	25
Tons displacement per inch immersion at normal draught	59.70
Capacity of engine-room feed tanks, tons	51
reserve feed-water compartments, tons	192

MAIN ENGINES.

There are two propelling engines, right and left, outboard turning when going ahead, and placed abreast in watertight compartments, separated by a middle-line bulkhead.

The engines are of the vertical, inverted-cylinder, direct-acting, four-cylinder, triple-expansion type. The order of the cylinders, beginning forward, is forward low pressure, high pressure, intermediate pressure and after low pressure. The cranks of the two forward engines are opposite, as are the cranks of the two after engines, the first pair being set at right angles with the second. The sequence of the cranks, therefore, is high pressure, intermediate pressure, forward low pressure and after low pressure.

The framing of the engines consists of forged columns trussed by forged-steel stays.

The engine bedplates are of cast steel, in three sections, supported on the keelson plates, and have seatings for the main bearings, columns and the turning engines.

The cylinders and valve chests are of the best quality of cast iron, fitted with working liners of close-grained cast iron as hard as can be properly worked. The space between the cylinder casings and liners and the space between the double walls of both heads are utilized for steam jackets, the steam being supplied at boiler pressure to the high-pressure cylinder

jackets and through reducing valves for the intermediate and the low-pressure jackets, successively, each having its respective drain through a trap to the feed tank.

The high-pressure and the intermediate-pressure cylinders touch at finished surfaces so disposed as to offer constraint against athwartship motion only.

On the casings flanges are cast for securing lagging. There are facings for the crosshead guides and other fittings; and there are brackets for the supporting columns and the tie rods.

The high-pressure piston is made of cast iron, the intermediate and the low-pressure pistons of cast steel, and all followers are of class "A" cast steel.

The high-pressure piston ring is solid, the other main piston rings are cut obliquely and fitted with a brass tongue piece and lug over which is fitted a limiting piece. All these rings are set out with "C" springs, each having equal tension.

Each piston rod is tapered to fit the piston and is secured by a nut having a locking plate. The lower end is fitted to a forged-steel crosshead to which is bolted a cast-steel slipper. This slipper is lined with white metal and works in a single bushing bolted to the cylinder facings at the upper end and to a cast-steel guide of "I" section at the lower end: this girder is supported by the inboard engine column.

The go-ahead guides are iron castings and are made hollow to contain a water jacket; the backing guides are of cast steel and bolted to the flanges on the go-ahead guides.

The connecting rods are high-grade steel forgings, forked at the top to span the crosshead and are "T"-headed at the bottom.

The crank shafts are in two sections, each carrying two cranks, coupling disk and raised seatings for the eccentrics. The latter are made in two parts, bolted firmly in place and secured by a key with adjusting pieces on either side.

The forward section of the crank shaft operates a shaft bilge pump.

The main valves are of the piston type, one for the high-

pressure and two each for the intermediate and low-pressure cylinders. The heads are of cast steel with lap-welded steel-pipe distance pieces riveted on; the packing rings are of cast iron turned larger than the bore of the valve chest, cut obliquely and bolted together to allow contraction but not expansion.

The valve stems carry balance pistons working in cylinders on the upper valve-chest covers; the tops of the high and of intermediate-pressure balance pistons are connected to the low-pressure receiver, and the tops of the low-pressure balance pistons are connected to the main exhaust pipe.

The bottom of the high-pressure valve stem carries composition gibs working in brackets secured to the lower valve-chest covers. The intermediate and the low-pressure valve stems are worked by a crosshead similarly guided.

The valve gear is of the Stephenson type, with double-box links and an independent linking arrangement on the reversing shaft.

REVERSING GEAR.

The reversing gear for each engine consists of a steam cylinder and an oil-controlling cylinder bolted to the high-pressure cylinder. The piston rod of the reversing gear, which is common to both cylinders, acts directly on the arm, keyed to the reversing shaft. The piston rod passes through the controlling cylinder with a uniform diameter.

The valve of the steam cylinder is of the piston pattern, of composition, working in composition-lined valve chest.

There is a by-pass valve on the oil cylinder, worked by a continuation of the stem of the steam-piston valve. These valves are worked by a floating lever, the primary motion being derived from the hand lever on the working platform and the second motion from the reversing shaft, all parts being so adjusted that the reversing shaft follows the motion of the hand lever and is firmly held when stopped. There is a stopcock in the by-pass pipe of the oil cylinder, and a pump for reversing by hand is connected to the oil cylinder with its lever convenient to the working platform. The by-pass pipes

are connected to the valve box of the hand pump in such a way as to leave the hand arrangements always in gear. The piston of the oil cylinder is packed by two cup leathers.

REVERSING SHAFT.

There is one reversing shaft for each engine, with an axial hole through it. It has arms for the reversing engine and for each link. Each reversing arm for the links is made with a slot fitted with a block, to which the extension links are attached. Each block is adjustable in the slot of its arm by a screw and hand wheel of an approved hand-locking device and is fitted with a suitable index. The slots in these arms are so arranged that the links may be thrown into full backward gear irrespective of the position of the block in the slot; and the length of the slots is such that cutoff may be varied from about 0.5 to 0.75 of the stroke.

TURNING ENGINES AND GEAR.

There is installed in each engine room a double engine for turning the main engine with steam of one hundred pounds pressure. This engine drives, by worm gearing, a second worm, which may be made, at will, to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves, and are made reversible by means of Stevenson links, reversed by hand levers.

Each turning-engine shaft is fitted for turning by hand.

The oil service is supplied with oil from a gravity tank fed by a small steam pump with overflow pipe to the pump suction. The piping arrangement is such that oil is distributed to all the oil boxes, which have adjusting valves and wick-feed to pipes leading to all bearings.

Water service is provided for each engine by a four-inch pipe from the discharge side of the main circulating pump. This pipe has suitable branches to the various parts of the engine; the discharge is returned to the suction side of the same pump by suitable pipe connections.

DATA OF MAIN ENGINES.

	H.P.		*I.P.*		*L.P.*	
Diameter of cylinders, each, inches	$38\frac{1}{2}$		$63\frac{1}{2}$		74	
Stroke, each, inches	48		48		48	
Diameter of piston rods, each, inches	$8\frac{1}{2}$		$8\frac{1}{2}$		$8\frac{1}{2}$	
Balance pistons, each, inches	7		7		9	
VALVES AND VALVE SETTINGS.						
Number of piston valves, each	1		2		2	
Diameter of valves, each, inches	23		$25\frac{1}{2}$		$28\frac{1}{2}$	
Travel of valve, each, inches	$10\frac{1}{2}$		$10\frac{1}{2}$		$10\frac{1}{2}$	
Side of valve on which steam taken	inside		outside		outside	
	Top.	*Bottom.*	*Top.*	*Bottom.*	*Top.*	*Bottom.*
Width of port, inches	4.0	4.0	4.0	4.0	4.0	4.0
Steam opening, linear, inches	$3\frac{3}{16}$	$3\frac{7}{16}$	$2\frac{15}{16}$	$3\frac{1}{8}$	$3\frac{1}{16}$	$3\frac{1}{8}$
area, square inches	175.7	189.5	359.8	382.8	422.6	431.2
Exhaust opening, linear, inches	4.0	4.0	4.0	4.0	4.0	4.0
area, square in.	220.5	220.5	490.0	490.0	552.0	552.0
Steam lap, inches	$2\frac{1}{16}$	$1\frac{15}{16}$	$2\frac{3}{16}$	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{8}$
Exhaust lap, inches	$-\frac{1}{4}$	$+\frac{7}{16}$	$-\frac{5}{16}$	$+\frac{5}{16}$	$+\frac{1}{16}$	$+\frac{1}{8}$
Steam lead, linear, inches	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{27}{32}$	$1\frac{1}{32}$	$\frac{31}{32}$	$1\frac{1}{32}$
Cut off, decimal of stroke, maximum	.835	.776	.777	.695	.788	.695
minimum	.596	.508	.536	.438	.555	.437
Diameter of crosshead bearings, in.	$10\frac{3}{4}$		$10\frac{3}{4}$		$10\frac{3}{4}$	
Length of crosshead bearings, in.	11		11		11	
Diameter of crank-pin bearings, in.	20		20		20	
Length of crank-pin bearings, in.	23		23		23	
Diameter of crank-shaft bearing, in.	$18\frac{1}{2}$		$18\frac{1}{2}$		$18\frac{1}{2}$	
Length of crank shaft bearing, Nos. 1, 2, 3, 4, 5, 6, inches	$22\frac{1}{2}$	$22\frac{1}{2}$	$22\frac{1}{2}$	$22\frac{1}{2}$	35	29
Axial hole crank shaft, inches	10		10		10	
Length of connecting rod between centers, inches	96		96		96	
Ratio to crank	1 : 4		1 : 4		1 : 4	

SHAFTING AND THRUST BEARING.

The thrust shaft is complete to the after section of the crank shaft and has twelve collars, between which are fitted cast-steel horseshoes lined with white metal, which are hollowed for circulating water. The horseshoes may be adjusted by nuts on the side rods, which are secured to cast-iron pedestals at each end. These pedestals are bolted to the sole plate, and are capable of being moved in a fore-and-aft direction by adjusting wedges. The pedestals with their ends and side walls form a trough for an oil bath which has in it a cooling coil.

The line shaft is forged on the thrust shaft and continues to the stern tube, where it couples to the stern-tube shafting. The latter is supported by two stern-tube bearings, which are of brass and fitted with lignum vitae.

The inboard coupling of this shaft is made so as to permit the shaft to be drawn outboard.

The outboard body of the propeller shaft is covered with a watertight composition sleeve shrunk on and then pinned.

Each propeller shaft is supported by strut and stern-bracket bearings fitted with lignum vitae bearing surfaces similar to those in the stern tube.

DATA FOR SHAFTING.

Diameter of thrust shaft, inches	$17\frac{3}{4}$
Number of collars	12
Diameter of collars, inches	27
Width of collars, inches	2
Space between collars, inches	4
Length of thrust shaft, feet and inches	25–$11\frac{1}{4}$
Diameter of shaft beyond thrust, inches	$17\frac{1}{2}$
Length of stem-tube shaft, feet and inches	...
Diameter of stem-tube shaft, inches	$18\frac{1}{2}$
Length of propeller shaft, feet and inches	48–$5\frac{5}{8}$
Diameter of propeller shaft, inches	$18\frac{3}{4}$
Axial hole, inches	$10\frac{1}{4}$
Thrust shoes, effective surface, square inches	2,618.52
Length of thrust-shaft bearings, (two) inches	18
line-shaft bearing, (one) inches	26
stem-tube bearings, forward, inches	$60\frac{7}{8}$
after, inches	$61\frac{1}{2}$
propeller-shaft bearings, forward, inches	$35\frac{3}{4}$
aft, inches	$60\frac{1}{4}$

PROPELLERS.

There are two three-bladed propellers, both outboard turning for ahead motion; the blades and hub are of manganese-bronze. The blades are a true screw at 22 feet 6 inches pitch, and the pitch is adjustable by having oval bolt holes in the flange of the blades. The hub is tapered to fit the shaft and keyed, the nut being securely locked. All under-water fittings are covered by casings and fair-water sleeves filled with resin and pitch to make them waterproof.

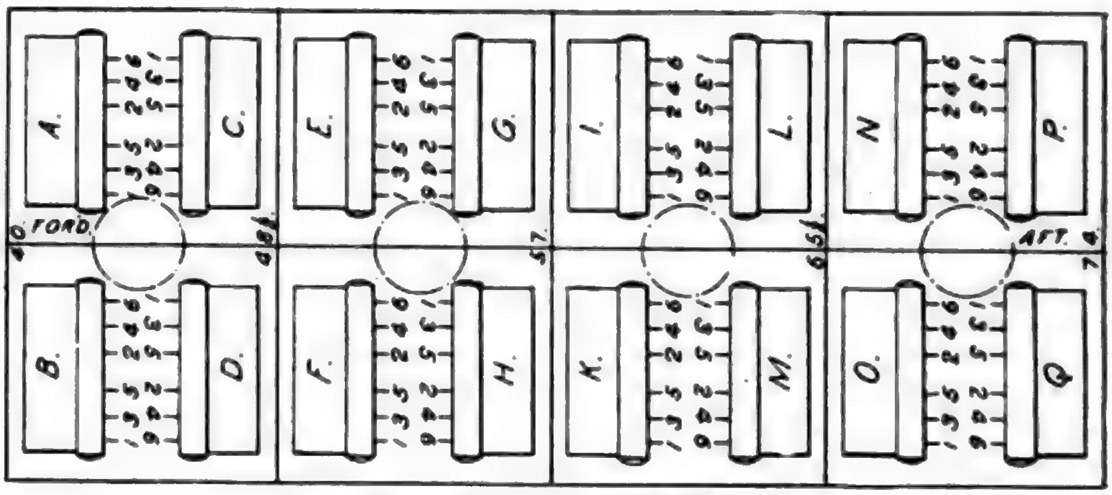
PROPELLER DATA.

Number of propellers	2
blades, each	3
Diameter, feet	18
Pitch as set, feet and inches	21–09

Pitch adjustable from, feet and inches	21–06 to 23–06
Ratio of diameter to pitch	.8
Area, projected, square feet	78
helicoidal, square feet	100
disk, square feet	254.47
Height of lower tip of blade above keel, inches	16.7
Immersion of upper tip of blade at load draught, inches	67.3

BOILERS.

The boilers are of the Babcock & Wilcox type, built and installed by that firm. The battery consists of sixteen boilers in eight watertight compartments, two in each, as shown:



Arrangement of Boilers.

The capacity of the boilers is such that all steam machinery can be run at full power with an average air pressure in the ash pit of not more than two inches of water. All pressure parts are made of open-hearth steel plate and seamless steel tubes with no screw joints exposed to the fire. The general design of the boilers is the usual type built by this well-known firm.

Each boiler has the following fittings:

One main steam stop valve closing toward the boiler and one dry pipe in the steam drum.

One main feed stop valve and check valve, with internal pipe.

One auxiliary-feed stop valve and check valve, with internal pipe.

One surface-blow valve with internal pipe and scum pan and two bottom-blow valves with internal pipes.

One main safety valve and one steam gauge.

Three gauge cocks arranged to operate from the fireroom floor.

Two glass water gauges, one of them being of the Klinger type, both being fitted with quick-closing devices.

One salinomiter pot, one drain cock and one air cock.

One stop valve, three-quarters of an inch in diameter, for cleaning pipe connections.

Two cleaning hose and lances.

One connection for testing water.

Necessary pipes and fittings for attaching all the above to boilers.

Zinc protectors with baskets for catching pieces of disintegrated zincs.

There are air connections for blowing soot off the tubes.

The uptakes have a clear area at all points of one-seventh of the grate, and are provided with dampers and doors for examination of their interior. The space between the inside and middle sheets is open to the air space of the smoke pipe at the top, and is provided with dampers at the bottom for the free circulation of air when forced draft is not used. These two sheets are free one from the other to allow for expansion. The space between the middle and outer sheets is filled with magnesia to prevent conduction of heat, and this lagging extends to the protective deck.

There are four smoke pipes, each about ninety-three feet in height above the grates. The inner casing extends to the top, and the outer casing extends to within eighteen feet of the top, between these two casings is the usual air space. The weight of the smoke pipe is taken by the protective deck. Each pipe divides into four rectangular sections, one for each of the boilers, as shown in the sketch.

DATA FOR BOILERS.

Number and type	16 B. & W.
Height, external, feet and inches	12–01½
Length, external, feet and inches	9–01½
Width, external, feet and inches	16–01½
Number of furnaces, each boiler	2
furnace doors, each boiler	6
headers, each boiler	27
Grate surface, square feet	99.375
Heating surface, square feet	4,250.
Ratio of G. S. to H. S., square feet	42.76
Grates, length, feet	7
width, feet	6.83
Per cent. of air space in grates, inches	35
Test pressure, pounds	400
Working pressure, designed, pounds	265
Number of tubes, 2-inch (No. 8 B. W. G. thickness)	901
4-inch (No. 6 B. W. G. thickness)	57
Smoke pipes, height above grate, feet	92.25
Area of smoke pipe, each, square feet	59.56
Number of smoke pipes	4
Grate area, each group, square feet	397.4
Kind of forced draft	closed fireroom.

ELECTRICAL FIRING DEVICE.

There is an electrical time-firing device in the starboard engine room, which is suitably connected to a gong on the light dials suitably located in each fireroom. The interval of firing the furnaces is controlled from the engine room, and this device is adjustable by seconds up to ten-minute intervals.

MAIN STEAM LINE.

The main steam pipes are arranged symmetrically in two systems, one on each side of the ship, and have an eight-inch branch from the auxiliary steam line in each compartment and so indirectly from each pair of boilers. The sizes of these pipes increase from forward aft, from eight to thirteen inches, the latter diameter continuing to the engines. Slip joints, bleeder pipes and separators are provided, as well as stop valves, which are suitably located in the lines of piping. There is provision for supplying live steam to the intermediate and the low-pressure receivers.

AUXILIARY STEAM LINE.

The auxiliary steam lines are eight inches in diameter and extend fore and aft through the boiler compartments, one on each side of the ship. They are connected with the main stop valves of all boilers on their own sides of the ship, and a cross connection is provided in the forward boiler compartments. Here the auxiliary steam line connects with the manifold which supplies steam to the machinery in the forward part of the vessel. A similar connection aft supplies steam to the machinery in the after part of the ship.

In connection with the auxiliary steam line there are the following systems:

Dynamo steam and exhaust piping.
Evaporator steam and exhaust piping.
Steam heating and pantry systems.
Ice machine steam and exhaust piping.
Anchor engine steam and exhaust piping.
Steering engine.
Galley steam.
Laundry steam.

OTHER SYSTEMS OF PIPING.

Other systems of piping are:
Main feed suction and discharge.
Auxiliary feed suction and discharge.
Bilge suction and discharge.
Reserve feed tank connection.
Distiller and evaporator piping.
Fresh-water piping.
Discharges from pump to fire mains.
Sanitary system.
Water service to main engines.
Drains.
Steam piping to sea valves.
Refrigerator piping.
Ice-machine water piping.

Vapor piping.
Safety-valve escape pipes.
Indicator piping.

TELEGRAPHS AND GONGS.

The engine-room telegraphs and the gongs are of the usual type and are operated from the conning tower, the bridges and the central station.

TELEPHONES AND SPEAKING TUBES.

Telephones of the loud-speaking type are installed so that communication is obtained where needed. Speaking tubes communicate from the central station, from the bridge and from engine room to various other stations.

ASH HOISTS.

The ash-hoist engines were designed and built by the Hyde Windlass Company, and are located in the upper hatches. The ventilators contain the bucket guides, ropes, sheaves, etc. The hoists may be operated either from the main or the upper deck, and are designed to hoist either to the main deck or to the upper deck, the bucket-guide rails extending from the bottom of the ventilator trunk to a point well above the upper deck. There are trolleys at this deck, as well as on the main deck, for delivering ash buckets to the chutes at the ship's side. On a test, three hundred pounds were hoisted from the fireroom floor plates to the upper deck in seven seconds, including starting and stopping, with 150 pounds of steam pressure.

The hoisting engines are of the reciprocating type, with a rope drum, fitted with a follow-up and reversing gear and an adjustable safety gear to prevent overwinding and to stop the engine when the bucket reaches the fireroom floor plate.

DATA FOR ONE ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	4½
Stroke, inches	5
Diameter of drum, inches	5
Number of ash-hoist engines in the ship	4

FORCED-DRAFT BLOWERS.

One forced-draft blower is located in each fireroom, being suspended from the protective deck over the center of the fireroom in its own airtight compartment. The engines and fans were designed and built by the B. F. Sturtevant Company.

Each engine drives two fans, located athwartships, thus delivering the air directly to the fireroom floor plates, about two feet in from the ash pan. The air is supplied from the fireroom ventilators, which are closed at the bottom when under forced draft.

DATA FOR ONE BLOWER ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	6
Stroke, inches	6
Diameter of valve, inches	$3\frac{1}{2}$
Valve travel, inches	2
Diameter of piston rod, inches	$1\frac{5}{16}$
crank shaft, inches	$3\frac{3}{16}$
pins, inches	$3\frac{3}{16}$
fan shaft, inches	$3\frac{3}{16}$
Length of connecting rod between centers, inches	$15\frac{1}{4}$
Number of bearings	3
Total length of bearings, center, inches	$3\frac{3}{8}$
end, inches	$10\frac{1}{2}$
Crank angle, degrees	180

DATA FOR ONE BLOWER FAN.

Diameter of fan, inches	66
Number of blades	8
Width of tip of blades, inches	16
Area of induction nozzle, square inches	1,383
eduction nozzle, square inches	2,765

FEED AND FILTER TANK.

A feed and filter tank of 6,040 gallons capacity is located on the outboard side of the after end of each engine room. It is rectangular in shape and the top is arranged as a filter, with a capacity of 1,000 gallons; the filtering material is "Loofa," which is placed between the perforated plates. This filtering chamber is divided by vertical division plates so arranged

that the water flows under and over in succession. All the material is of steel which has been galvanized before assembling.

TANKS.

There are oil tanks of 3,000 gallons capacity. There are tallow tanks of 150 pounds capacity. There are two waste tanks of 500 pounds capacity each.

MACHINE SHOP.

The machine shop is located amidships, on a level with the battle gratings and in a compartment of its own between the engine-room hatches. Each machine is directly driven by its own motor. The following machines are installed:

One 28-inch extension gap lathe (11 feet).
One 14-inch engine lathe (4 feet).
Two 12-inch engine lathes (5 feet).
One 16-inch shaper.
One 28-inch vertical drill press.
One 12-inch vertical drill press.
One Universal milling machine.
One 30-inch grindstone.
One 12-inch emery grinder.
One combined hand punch and shears ($5\frac{1}{2}$ inches).
Six bench vises.

All tools are complete and provided with the most modern attachments, including scroll and drill chucks, index heads automatic crossfeed, swivel tables, pipe vises, etc., and all necessary tools, drills and cutters.

HEATING SYSTEMS.

The heating system is divided into five sections, three forward and two aft, each supplied by the auxiliary steam line through stop and reducing valves set at forty pounds per square inch. Three of these sections constitute distinctly separate circuits. One circuit supplies the galley, general mess pantry, bakery and forward laundry; the other, all for-

ward baths, showers, heaters and after laundry; the third, all after bath showers, heaters and pantries. Two sections constitute two distinctly separate radiator systems, which derive their supply from distributing manifolds, one forward and one aft, fitted with independent stop valves; six forward radiator circuits branch off from these manifolds. Whenever the galley and heater circuits change direction to supply remote heaters, suitable cut-off valves are provided. The drains from the forward and the after radiators are divided into three respective circuits and enter separate receiving manifolds forward and aft respectively; the forward and the after galley, pantries and bath circuits lead into separate forward and after traps respectively. The radiator manifolds are each drained by an independent trap.

All traps discharge through main steam drain line into the feed tank and are fitted with suitable by-pass and stop valves to discharge into the starboard auxiliary condenser. The heater-circuit steam and drain pipes are of seamless-drawn brass (iron-pipe size) suitably connected by composition fittings, made tight where passing through bulkheads by stuffing boxes and located as near to the door as possible when passing through store rooms.

Provisions for ample expansion have been made by fitting horizontal copper U bends having the same internal diameter as the connecting pipes. The radiators consist of brass pipes connected by return bends with reduced ends. They are fitted generally with drain, supply stop valves, triangular stems for socket keys, protected by stem guards, but have hand wheels in officers' quarters.

Whenever areas over ten square feet are called for the radiator coils are divided into two parts, unions being fitted on outlet ends of valve to permit of unrestricted removal of coils. In order to expedite service and repairs, all heaters and radiators are tagged by suitable brass tags bearing numbers, odd and even, from forward to aft, on each deck, according to location on starboard and port side, respectively.

REFRIGERATING PLANT.

There are two Allen dense-air ice machines, each capable of producing the cooling effect of two tons of ice per day. The cooling pipes from the machines are led into the ice tank, the scuttlebutts and the cold-storage room.

Valves are provided in accordance with the Bureau of Steam Engineering standard arrangement of valves, in the cold-air pipes of refrigerating plant, so that the air may go to the cold-storage room direct, or through the ice-making tank, and thence to the cold-storage room and scuttlebutts, and also from the ice-making tank direct to the scuttlebutts.

AIR COMPRESSORS.

There are three Westinghouse air compressors in the after part of the port engine room for use in running pneumatic tools in the Steam Engineering department, for blowing soot off the boiler tubes, and for the gas-ejecting system for the guns.

Each compressor has a capacity of about fifty cubic feet of free air per minute, at one hundred pounds pressure. The compressor is driven by steam.

CONDENSERS.

Main Condenser.—There is one main condenser in each engine room, oval in form, the inside dimensions being 9 feet 4 inches high, 5 feet 8 inches wide, the top and bottom being struck with a radius of 2 feet 10 inches. The shell is $\frac{5}{16}$-inch thick, with two double butt joints, and with circumferential and longitudinal angle and T-bar stiffeners.

The water chests are cast $\frac{5}{8}$-inch thick. The forward chest, being the one for the entrance and exit of circulating water, has a horizontal division plate in the middle fitted with valves which, when open, allow the circulating water to pass overboard direct, the valves being worked by a lever on the outside of the condenser, and it has nozzles for inlet and outlet of circulating water 21 inches in diameter.

The condenser-tube sheets are rolled, each in one piece. They are 1 inch thick, with smoothly finished holes for the tubes, tapped and fitted with screw glands for packing the tubes.

There are 6,292 seamless-drawn tubes in each condenser, $\frac{5}{8}$-inch outside diameter, No. 16 B. W. G. in thickness. The tubes are 14 feet and $\frac{1}{2}$ inch long between tube sheets and are spaced $\frac{15}{16}$-inch between centers. They are supported at two intermediate points by ferrules, $\frac{3}{4}$-inch long, inserted in supporting plates. Baffle plates are fitted to direct the steam over all the tubes.

The cooling surface for each condenser is 14,411 square feet, measured on the outside of the tubes.

The condensers are supported by angle plates riveted between circumferential angle-bar stiffeners.

There is riveted to the shell of each condenser a casting with two composition nozzles with faced flanges 27 inches diameter of opening, for attachment of the main exhaust pipes, and a faced flange, 9 inches in diameter of opening, for the auxiliary exhaust pipe.

Cast-steel flanges are riveted to the shell of each condenser and properly faced for an air-pump suction pipe 13 inches in diameter and for two manholes at the bottom 12 inches in diameter. There is a 1-inch connection in the bottom manhole for cleaning the tubes by boiling.

Drain cocks are provided with pipes leading to the bilge.

A copper tank is provided for admitting an alkaline solution into each condenser, the tank having a capacity of five gallons. Zinc protectors and safety valves are fitted.

The material of the condenser is as follows: Shells, steel, class B boiler plate. Baffle plates, steel, class C boiler plates. Tubes, composition: copper 70, tin 1, zinc 29 per cent. Tube sheets and supporting plates are as near as possible the same material as the tubes. Glands are of tubing, and of the same composition as the tubes. Water chests are of composition. All bolts are of bronze.

MAIN AIR PUMPS.

There is one independent air pump for each main engine, which is capable of maintaining a vacuum of twenty-five inches at full power. Each is double, vertical and single acting, with two inverted steam cylinders. The suction opening is thirteen inches and discharge is eleven inches in diameter.

The casings are of composition, the steam cylinders are cast iron and air-pump brackets are of composition.

MAIN CIRCULATING PUMPS.

The circulating water for auxiliary condenser is supplied by a centrifugal pump having double inlet valves, and it is driven by an independent compound engine of sufficient power to discharge 15,000 gallons of water per minute when making two hundred and sixty-five revolutions per minute.

AUXILIARY AND DYNAMO CONDENSERS.

The material of these condensers is as follows: Shells, steel, class B, boiler plate; tubes, composition, copper 70, tin 1, zinc 29 per cent.; tube sheets, as near as possible of the same material as the tubes; heads, composition.

The cooling surface of the auxiliary condensers is 600 square feet, and of the dynamo condensers 700 square feet, measured on the outside of the tubes.

In each engine room there is an auxiliary condenser connected from the auxiliary exhaust pipe to all the auxiliary machinery. Each condenser has a combined air and a circulating pump.

For each dynamo room there is an auxiliary condenser for the exclusive use of the dynamo engines. Each has a combined air and circulating pump. The tube sheets are one inch thick. The diameter and spacing of the tubes and the packing are the same as in the main condensers.

The tubes of the auxiliary and dynamo condensers are of the same length.

EVAPORATOR AND DISTILLING PLANT.

The evaporator and distilling plant is placed on the protective deck. There are four evaporators and four distillers, with their accessories.

The evaporators have a combined capacity of 23,000 gallons of water per 24 hours.

The distillers have a combined capacity of 23,000 gallons of potable water per 24 hours.

The evaporators take steam from the auxiliary steam pipe, and the coil drain pipes lead through a by-pass, automatic traps, to the feed tanks. The evaporator-feed and fresh-water pump takes steam from the evaporator coils, as well as from the auxiliary steam pipe.

The shells of the evaporators have connections with valves and pipes for directing the steam into the distillers and into the auxiliary exhaust pipe.

The feed water for the evaporators is taken from the circulating pipe, after it has passed from the sea and through the distillers.

There are blow pipes of ample size, so arranged that the evaporators may be blown out when working under pressure.

The distiller circulating pumps discharge to the distillers, the water passing overboard or into the sanitary system at will. There is also a direct connection from this pump to the flushing pipes, and the relief valve for the distiller is so placed as to act for both the distillers and the flushing system.

In addition to the pump connection for distiller circulating, provision is made for circulating water through the distillers, from a conveniently located discharge pipe from a pump discharging to the fire main.

A small reservoir tank, fitted with a removable cover, is placed in the fresh-water pump suction between the pump and the distillers.

A water meter, without lead, is placed in the pipe connecting the reservoir tank with the bottom of the distillers.

Evaporators.—There are four horizontal evaporators, each having three hundred and twenty square feet of tube-heating surface. The tubes are two inches outside diameter and are without bends.

The tubes are secured to the tube sheets so that adequate provision is made for expansion, and the tubes are so arranged that their removal will leave the shell accessible in all its parts for scaling. All tubes are easily removable for cleaning and repairs, and there are no internal detachable joints in the tubes.

Distillers.—There are four distillers, each having one hundred and fifteen square feet of tube-cooling surface, measured on the outside of the tubes.

The tubes are straight, $\frac{5}{8}$-inch outside diameter, tinned on both sides and well expanded and sweated into tube sheets. Provision is made for the expansion of the tubes by the use of a flange tube sheet working in a stuffing box.

FEED-WATER HEATERS.

In each engine room there is a feed-water heater with all necessary fittings complete.

The heating surface of each heater is 1,150 square feet, measured on the outside of the tubes. They are of the direct-flow type, located on the discharge side of the main feed pump.

The heating agent is the auxiliary exhaust steam. The tubes are $\frac{5}{8}$-inch outside diameter, No. 16 B.W.G.

PUMPS.

The pumps are in accordance with the table on the following page.

PUMPS.

Auxiliary.	Number.	Type, make and location.	Steam cylinders. Number.	Steam cylinders. Diameter, inches.	Steam cylinders. Diameter piston rod, inches.	Steam cylinders. Stroke, inches.	Steam cylinders. Constant "K" (mean of both ends).	Water cylinders. Number.	Water cylinders. Diameter, inches.	Water cylinders. Diameter piston rod, inches.	Water cylinders. Stroke, inches.
Main air pumps.	2	Cameron, twin, vertical bucket, single-acting, one in each engine room.	2	14	2½	18	.00686	2	35	3½	18
Main circ. pumps.	2	Centrifugal, driven by compound engine, one in each engine room.	2	H.P., 11	2¼	10	.00235	...	...	...	...
				L. P., 22	2¼	10	.00955	...	...	...	...
Main feed pumps.	4	Cameron, vertical piston, double-acting, single, two in each engine room.	1	16	2½	18	.009	1	10	3	18
Aux. feed pumps.	4	Cameron, vertical piston, double-acting, single, one in each starboard fireroom.	1	12	2¼	12	.00337	1	8	2¼	12
Reserve feed-water pump.	1	Cameron, vertical piston, double-acting, single, starboard engine room.	1	5	1	6	.00029	1	6	1	6
Fire and bilge pumps.	6	Cameron, vertical piston, double-acting, single, one in each engine room.	1	12	2¼	12	.00337	1	10	2½	12
		One in each port fireroom.	1	10	1¾	12	.00234	1	8	2	12
Auxiliary condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1¼	12	.00084	1	10	1¼	12
Dynamo condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1¼	12	.00084	1	10	1¼	12
Evaporat. and distill. plant.	2	Evaporating feed pump, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	2	Distilling fresh-water pumps, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	1	Distilling circulating pump, Cameron, horizontal piston, double-acting, single, starboard evaporating room.	1	12	2¼	12	.00337	1	14	2½	12
Ice machine.	1	Distilling circulating pump, centrifugal, driven by de Laval st. turbine, port evaporating room.	...	...	...	...	...	...	...	...	...
	1	Allen dense-air, H. B. Roelker, berth deck, starboard, forward.	1	9½	1⅝	13	.00242	...	...	...	...

PUMPS AND PUMP CONNECTIONS.

No.	Pumps.	Size, inches.	Kind.	in.	Suction pipes from	in.	Discharge pipes to—	Location.
2	Main air	2 14 inch, 2 35 inch, by 18.	Twin, vertical bucket, single acting.	13	Condenser	11	Main feed tanks	One in each engine room.
2	Main circulat'g	Centrifugal	Vertical compound	21	Sea	21	Condenser	One in each engine room.
				13½	Main drain	21	Overboard.	
4	Main feed	18 by 10 by 18	Ver. piston, double-acting, single.	5	Feed-tank connecting pipe	5	Main-feed discharge main	Two in each engine room.
				5	*Channel ways	5	*Main feed tanks.	
4	Fireroom feed	12 by 8 by 12	Ver. piston, double-acting, single.	3	Bottom blows in at'wartship compartments.	4	Auxiliary feed main	One in each starboard boiler room.
				3½	*C. and R. pipes from ship's sides	3½	*Main feed tanks.	
				4	Feed suction pipe	3½	*Reserve feed-water tanks.	
				3½	*Reserve feed-water tanks	5	Overboard in port compartment. Fire extinguisher.	
4	Fireroom fire and bilge	10 by 8 by 12	Ver. piston, double-acting, single	4	Fireroom floors in starboard and port compartments.	4	Fire main	One in each port boiler room.
				4	Sea	4	Overboard in same compartment.	
				4	C. and R. drainage manifolds	2½	Hose connection.	
				1½	Hose connection.			
2	Fire and bilge	12 by 10 by 12	Ver. piston, double-acting, single	5	Sea	5	Fire main	One in each engine room.
				5	Engine-room bilge	5	Overboard.	
				5	Crank pits	2½	Hose connection.	
				4½	Shaft alley.			
				1½	Hose connection.			
				5	C. and R. drainage manifolds.			
1	Res. feed water	5 by 6 by 6	Ver. piston, double-acting, single	5	Reserve feed-water tanks	7½	Feed-tank connecting pipe. Reserve feed-water tanks.	Stbd. engine room.
2	Shaft bilge	Capac. of each about 480 cu. in. per stroke.	Plunger, single acting	4½	Engine-room bilges	4½	Overboard	One in each engine room.
				4½	Crank pits in same compartment.			
				4½	Shaft alley.			
2	Distiller circulating.	1 12 by 14 by 12.	Hor. piston, double-acting, single.	..	Sea	..	Distillers. Sanitary system. Fire main.	Stbd. evaporator rm.
		1 15-H.P.	Steam turbine	..		..		Port evaporator rm.
2	Auxiliary air and circulating	6 by 10 by 10 by 12.	Combined	5	Auxiliary condenser	3½	Main feed tanks	One in each engine room.
				5½	Sea	5½	Auxiliary condenser.	
2	Dynamo air and circulating.	6 by 10 by 10 by 12.	Combined	5	Dynamo condenser	3½	Main feed tanks	One for ea. dynamo rm. in engine rms.
				5½	Sea	5½	Dynamo condenser.	
2	Evaporat. feed.	4½ by 4 by 4	Light service	..	Sea	..	Evaporators	Starboard and port evaporator rooms.
					Distiller circulating water discharge.			
2	Distiller fresh water	4½ by 4 by 4	Vertical pist'n, light service.	..	Bottom of distillers	..	Fresh-water tanks. Main feed tanks. Reserve feed-water tanks.	Starboard and port.
2	Engine-room oil	[illegible] by [illegible] by 4	Piston, with hand attachment	..	Oil storage tanks	..	Distributing tank, with overflow pipe [illegible]	One in each engine room.

* Connections for [illegible] pumps only.

WEIGHTS OF PROPELLING MACHINERY.

The contract weight of the propelling machinery and boilers was 2,060 tons, the actual weight was 2,106 tons, or 46 tons overweight. Below we find the weights in detail and the sum total.

	Pounds.
Cylinders of main engines	391,174.0
Shafting	279,008.0
Main engine framing and bearings	306.919.5
Reciprocating parts of main engines	111,629.0
Main engine valve gear	85,999.0
Main condensers	125,453.0
Main air and circulating pumps	61,782.0
Propellers	66,743.0
Boilers	1,062,971.0
Boiler fittings	391,059.6
Smoke pipes and uptakes	458,687.0
Steam and exhaust piping and valves	159,029.0
Suction and discharge piping and valves	142,148.4
Lagging and clothing	38,449.4
Flooring, gratings, etc	116,892.0
Auxiliaries	107,093.0
Fittings and gear	105,361.5
Water	369,696.0
Stores, tools and spare parts	153,222.0
Miscellaneous machinery	160,629.0
Connections under steam engineering to other miscellaneous machinery	23,664.0
Total	4,717,608.4
Total weight above, tons	2,106.075
Less:	
Contract weight, tons	2,060.0
Authorized changes, tons	2.59
Spare crank-shaft, propeller blades and evaporator spares, tons	40.190
Water in evaporators and distillers, tons (13,410)	5.986
feed and filter tanks (65,600)	29.285
Total	2,097.761
Net weight in excess of contract weight, tons	91.686

ELECTRIC PLANT.

There are two dynamo rooms, one on the starboard and one on the port side of the midship line. They are on the upper platform deck just abaft the forward engine-room bulkhead and just below the protective deck.

In each dynamo room there are three eight-pole, compound-wound 100-kilowatt generators, each of these generators being capable of delivering 800 ampères of current at 125 volts when running under full load at three hundred and fifty revolutions per minute, with a shunt current of nine ampères.

The engines are compound, inverted type, with high and low-pressure cylinders of ten and eighteen inches diameter respectively.

The crank pits of the engines are used as oil wells. Oil from these wells is pumped around the bearing surfaces by means of a plunger pump connected to an eccentric on the crank shaft; the oil is drawn through a strainer past an inlet check valve and forced past an outlet check valve to the main feed pipe; the latter has a relief valve operated by hand through which excess pressure in the lubricating system may be reduced and the excess oil allowed to run back into the well. From the main oil-feed pipe branches are run to the main bearings by means of holes in the journals connecting with holes in the rock and crank pins; the crank pins are lubricated; small pipes lead from the crank-pin bearings along the connecting rods to the wrist pins which are thus lubricated, together with the slides. Holes in the slides permit the escape of the oil to the oil wells.

Another branch from the main oil-feed pipe goes to an indicator glass through which the drip of the oil to the valve slide and the eccentrics can be seen and regulated.

To prevent oil from getting into the steam cylinders and thus back into the boilers a form of stuffing box is used; this box has brushes and is packed with asbestos, thus keeping the heavy oil out of the low-pressure cylinders.

The speed of the engine is regulated by means of a spring

governor. The steam pressure used is 150 pounds, which is regulated by means of a Leslie reducing valve.

The dynamo steam lines, one from each dynamo room, lead off from the auxiliary steam lines of the ship; between the dynamo rooms there is a cross connection, which may be used to connect one dynamo room with the steam line of the other in case of necessity.

In each engine room there is a separator and a trap for separating water from the steam and draining it off.

On the generator panel of each dynamo switchboard there are three circuit breakers, one for each machine. For each generator there are two single-pole, single-throw switches, one for power, one for lighting and a common negative, besides equalizer switches.

On the right and on the left ends of the generator panel there is a panel having two circuit breakers, one for lighting and the other for power. By throwing in these circuit breakers properly, light and power may be obtained from the generators in either the starboard or the port dynamo rooms or from both.

In the distribution rooms, which are just forward of the dynamo rooms proper, there are distribution boards, each of which has three panels, one for lighting, one for power and one for the turrets.

Each panel has a double-pole, double-throw switch, by means of which the power may be taken from either the starboard or the port dynamos. On the lighting panel there are ten double-pole, single-throw circuit switches and three double-pole circuit breakers for the searchlight circuit, besides a lighting voltmeter, lighting ammeter, a searchlight voltmeter and three searchlight ammeters. On the power panel there are twenty-six double-pole, single-throw circuit switches, twenty-one of which are in use, a voltmeter ground detector, power and turret voltmeters, a power ammeter and a turret ammeter. The third panel of this board is the turret panel, which has a switch for the forward turret-turning-

motor generator, another for the after turret-turning-motor generator, and one for ordnance power in the forward and the after turrets.

ANCHOR WINDLASS.

The anchor windlass is of the vertical type and has two vertical shafts driven by worm gearing direct from a worm located on the crank shaft of the engine, without the intervention of counter shafts or beveled gears. Each shaft carries on its upper end, above the main deck, a wildcat or locking gear complete. The arrangement is such that the wildcats can be operated together or independently of each other. The wildcats revolve in a horizontal plane, taking in each bower chain on the inboard side and the sheet chain on the outboard side of the wildcats. The vertical shafts have couplings, and the lower end is keyed and supported by steady bearings.

The wildcat is cast from the best open-hearth steel to suit the $2\frac{3}{4}$-inch cable, as manufactured by the Government.

Each wildcat is fitted with a positive locking device worked by raised cams on the periphery of the locking rim, and slotted keys operated by means of a lever. The entire operation of locking or unlocking the wildcat can be accomplished by one motion of the lever through an angle not exceeding sixty degrees.

A friction-band brake is fitted to each wildcat. The brakes have sufficient surface and ample strength in all parts to "ride by" with the windlass unlocked. Each end of the friction band is provided with a compressor, so that the bower or starboard chain can be checked when running out. The compressor is controlled by a screw hand wheel set close to the wildcat.

The windlass engine is designed for a working steam pressure of one hundred and fifty pounds per square inch, but is able to withstand the full boiler pressure.

The windlass was fully tested on the official trials of the vessel as follows:

The starboard anchor was let go in thirty-three fathoms of water and the chain veered to sixty fathoms; then the port anchor was let go and both chains veered until the starboard ninety-fathom shackle was at the hawse pipe and the port sixty-fathom shackle at the controller. The wildcats were connected, and both chains hove in simultaneously, at a uniform speed, until the port anchor was at the hawse pipe. The rate of heaving in both chains together was six fathoms in 42.6 seconds. The port anchor was at the hawse pipe in 6 minutes 52 seconds. The port wildcat was disconnected and the starboard anchor was up in 3 minutes and 42 seconds. The wildcats took the shackles and swivel without surging. There was no heating of the thrust block or worm wheels.

STEERING GEAR.

The main steering arrangement consists of a right-and-left-handed forged-steel screw, connected through bushed cast-steel driving nuts and forged-steel side links direct to the crosshead on the rudder stock. The right-and-left-handed screw proper is connected by a lug clutch to another section of shafting, which shafting connects to the steering-engine crank shaft through a pair of herring-bone gears, the large gear being provided with a sliding clutch for throwing the engine in and out of gear. By throwing out this sliding clutch the steering engine may be thrown out of gear, in which condition the hand-steering wheels in the steering-engine room may be used for steering through the screw by throwing in clutch at forward end of the screw shaft; or, by leaving both of these clutches out and throwing in clutch on hand-steering wheel shaft, the rudder may be operated through the relieving tackle direct from hand-steering wheels to crosshead.

To put the rudder from hard over to hard over through the working angle of 70 degrees requires about 18 turns of the regular hand-steering wheels forward and 10¾ turns of the trick wheel at the steering engine; requires 48 turns of the hand-steering wheels in the steering-engine room, when work-

ing through the relieving tackle; requires $20\frac{3}{4}$ revolutions of the screw shaft and 85 revolutions of the engine.

The rudder, which is of the balanced type, has an area of about 274 square feet. The main frame is a steel casting, with wrought-iron boundary frame and cross bracing of flanged plates and angles, the interior being filled with white pine and the interstices with a mixture of half pitch and half tar, the whole being covered with $17\frac{1}{2}$-pound plating.

The weight of the rudder is taken on a bearing at the top of the stern casting, with a floating friction ring between the crosshead casting and the stern casting. The crosshead casting has a horizontal, circular bearing surface at its upper end for the friction-band brake, which is operated by a hand wheel on the forward side of the bulkhead No. $116\frac{1}{4}$ through a long connecting rod and a bell-crank lever.

The steering engine is a 15×12-inch, double-cylinder, combined hand and steam-steering engine, manufactured by Messrs. Williamson Bros. Co., of Philadelphia, Pa. It is designed for a working pressure of 150 pounds per square inch, but is capable of withstanding full boiler pressure. The steam pressure for this engine is regulated by means of a reducing valve located on the after side of bulkhead No. 79, in the port engine room.

The operation of the engine by steam may be controlled either through wire-rope transmission from the steering stations forward, or by the hand wheel on the after end of the engine.

Steering Stations Forward.—The steering stations forward are located in the communication room, conning tower and pilot house. By means of a double-jaw-type clutch the communication-room wheel may be thrown into gear and the other two thrown out, or vice versa. In using the wheel in the pilot house the conning-tower wheel may be thrown out by moving it aft on its shaft. In using the conning-tower wheel the pilot-house wheel may be thrown out by disconnecting the shafting just above the conning-tower steering standard.

All shafting, except within 12 feet of compass, is cold-rolled steel, and all gears are composition with cut teeth.

Steering wheels are arranged so that when the tops of wheels go to port the helm goes to starboard and bow goes to port.

Electric helm indicators and electric-steering telegraph transmitters are located in the communication room and pilot house.

Steering Stations Aft.—The after stations are both in the steering-engine room. One consists of the trick wheel connected directly to the operating shaft of the engine, the other consists of three large hand wheels on the same shaft, properly fitted, as described, with large clutches for steering, either through the screw shaft direct or through the relieving tackle.

The relieving tackle consists principally of rope drum, operating by the hand-steering wheels through a pair of bevel gears and a worm and worm wheel, on which is wound 1-inch-diameter wire rope, one end of rope leading out to port and one to starboard, and thence both aft over sheaves and through stuffing boxes in bulkhead No. 116½, and operating on the side rods through one single and one double sheave on each side of ship, the standing part of all being connected by turnbuckle to special stiffener on after side of bulkhead No. 116½.

Both the trick wheel on the engine and the large steering wheels are so arranged that when the top of the wheel goes to port the bow goes to port also.

A mechanical helm indicator is connected directly to the driving nut on the port side, and in the steering-engine room are located an electrical helm indicator and an electrical steering-telegraph indicator. Arrangement of clutches aft.

Attention is called to the fact that there is a possibility of the locking pin in the nut for engaging the locking disc with the herring-bone gear on the main shaft falling in the wrong slot. Care should therefore be exercised to be sure that this pin has fallen in the proper slot.

DESCRIPTION OF VENTILATION.

On this vessel all the compartments below the gun deck and the captain's cabin, the wardroom dining room, the armory, the bakery, the various water closets and wash rooms on the gun deck are provided with artificial ventilation.

Ventilation systems—either supply, exhaust, or both combined, but suitable to the requirements in each particular locality—are provided for the compartments in the various subdivisions of the ship, thus providing a positive circulation of air by means of electric blowers.

Arrangement.	Compartments ventilated.	Blower.			Style.	Location.			Type.
		No.	H. P.	Cap'y.		Deck.	Side.	Frame.	
1	Seamen's head.........	1	2.5	4,000	S. P.	Gun	P.	7–8	Exh.
2	Quarters and stores, for'd, fr., No. 23.	2	1.75	2,500	S. P.	Berth	S.	11	Sup.
3	Quarters and magazines, between frs. Nos. 23 and 40.	3	1.75	2,500	S. P.	Berth	S.	29-30	Sup.
		4	1.75	2,500	S. P.	Berth	P.	26–30	Sup.
		5	3.5	5,000	S. P.	Berth	S.	35–36	Sup.
		6	3.5	5,000	S. P.	Berth	P.	35-36	Sup.
4	Coal bunkers, washroom and passages between frs. Nos. 35 and 79	7	1.75	2,500	S. P.	Main	S.	46	Exh.
		8	1.75	2,500	S. P.	Main	S.	51	Exh.
		9	1.75	2,500	S. P.	Main	S.	63	Exh.
		10	1.75	2,500	S. P.	Main	S.	71-72	Exh.
5	Dynamo rooms and evaporator rooms.	11	6.50	10,000	S. P.	Gun	S.	75–76	Sup.
		12	6.50	10,000	S. P.	Gun	P.	75–76	Sup.
6	Berth and gun decks between frs. Nos. 76 and 95.	13	1.75	2,500	S. P.	Gun	S.	81–82	Sup.
		14	1.75	2,500	S. P.	Gun	P.	81–82	Sup.
		15	.4	600	C. S.	Gun	S.	89–90	Exh.
		16	.4	600	C. S.	Gun	P.	89–90	Exh.
7	Engine rooms..........	17	7.5	12,000	S. P.	Gun	S.	91	Sup.
		18	7.5	12,000	S. P.	Gun	P.	91	Sup.
8	Quarters, stores and magazines between frs. Nos. 93 and 105.	19	1.75	2,500	S. P.	Gun	S.	90–91	Sup.
		20	1.75	2,500	S. P.	Berth	P.	98-99	Sup.
		21	1.75	2,500	S. P.	Berth	S.	98-99	Sup.
9	Quarters and stores aft fr. No. 105.	23	2.5	4,000	S. P.	Berth	C.	122	Sup.
10	Steering engine room.	22	1.75	2,500	S. P.	S. En. room	S.	114	Sup.

All estimates for changing air in the different compartments are based on the gross volume of the compartments.

In the preceding table the capacities of the blowers are given in cubic feet per minute at one-ounce pressure. S. P. is steel-plate blower and C. S. is cast-shell blower.

VENTILATION SYSTEM.

The air is renewed in the various spaces approximately as follows:

Officers' quarters and crew space, berth deck outside of armor bulkheads, in from ten to twelve minutes.

Officers' quarters and crew space, berth deck inside of armor bulkheads, in about four minutes.

Water closets and crews' head in two to four minutes.

Wash rooms one to three minutes.

Store rooms and passages in six to eleven minutes.

Magazines in from six to eight minutes.

Engine rooms and steering compartments in about three minutes.

Evaporator rooms in about two minutes.

Dynamo rooms in about three-fourths of a minute.

This ventilation is provided by twenty-two electrically-driven fans, manufactured by the B. F. Sturtevant Company, Boston, Mass. Size, type and location given in table above.

None of the principal longitudinal or transversed watertight bulkheads of the ship have been pierced by the ventilation ducts where possible to avoid it. No ducts have been carried through the transversed slopes of the protective deck, but in all cases through the flat and fore-and-aft slopes. Where ducts pass through protective deck they are made watertight to the highest practical point above the berth deck. All ducts passing through the magazines are galvanized-steel seamless tubing or built of heavy-gauge steel worked watertight. A natural exhaust duct, equal to the area of mechanical supply duct, has been provided for each magazine and located as far as practicable from supply duct. The upper ends of the ducts are carried up close to the gun deck

and inside of the barbettes where practicable, and terminate there with a gooseneck, the lower end of which is bell-mouthed and covered with wire mesh.

McCerry, or equally effective adjustable elbows, fitted with butterfly dampers, have been used for supply terminals in all quarters, living spaces and elsewhere. In the quarters they are nickle-plated and in other places galvanized. All openings of these elbows are fitted with portable wire mesh. All other terminals are stationary.

All cowls have been installed where necessary for fan inlets or exhausts over bakery, galley, etc. Where any of the cowls interfere with the working of the guns or where necessary for cleaning decks they are made portable at the weather decks, and where such cowls are too high above the weather decks to be easily reached they are fitted with operating gear worked from weather decks. Where required, cowls under awning have been provided with wire-mesh screens.

The ventilation for the coal bunkers has been arranged with ducts of galvanized-steel tubing or built of heavy-gauge material. Valves and dampers have been fitted for this system, and all openings into bunkers have been covered with wire mesh to keep coal out of ducts.

Especial attention has been paid to the ventilation arrangements provided to avoid the transmission of heat from the engine and boiler rooms to other parts of the vessel. In wake of the boiler rooms an air casing under protective deck and on the inboard side of berth deck coal-bunker bulkheads has been fitted and connected to ship's ventilation for supply, and to the funnel casings for natural exhaust. The under side of protective deck within the engine rooms has been fitted with sheathing, with an air space allowed, and connected to the engine-room ventilation system for supply and to the engine-room hatches for exhaust.

For ventilating the two engine rooms there are two fans so arranged that one fan supplies the starboard engine room and the other the port. Branches have been led from the main to all working stations, platforms, air casing and corners of the rooms where required for efficient ventilation.

DRAINAGE SYSTEM.

The following is a general description of the drainage system, the features covered being as follows:

1. 15½-inch main drain.
2. 5½-inch secondary drain.
3. 4⅝-inch double-bottom drain (2 sections).
4. 4⅝-inch forward-bilge drain.
5. 4⅝-inch aft-bilge drain.
6. 4⅛-inch independent drain. F. R. (Bu. S. E.) eight of them.
7. 5-inch independent drain, E. R. (Bu. S. E.) two of them.

Main Drain.—This is 15½ inches diameter throughout its entire length. It is located on the starboard side close to the center line and extends from midway of forward fireroom to forward end of engine room, where it branches and runs athwartships, each branch connecting to a centrifugal pump.

A 15½-inch stop-check valve is located in each fire and engine room, those in the starboard fire and engine rooms being in and forming part of main system; the valve in port fire rooms being connected through center-line bulkhead to the line in starboard firerooms. All these 15½-inch stop-check valves are operated at the valves and also in central ammunition passage.

In both engine rooms, at frame 75, there is a 5-inch connection between the main drain and the C. & R. manifold numbers 6 and 7 located at frames 78 and 79. This manifold is connected to the fire and bilge pumps in the fire and engine rooms.

Secondary Drain.—This is 5½ inches diameter throughout its entire length. It has connection to all fire and bilge pumps through the C. & R. and S. E. manifolds; also to the handy-billy pump manifold located on the upper platform, forward, frames 34 and 35; aft, frames 94 and 95. The forward connection is made directly to the forward fireroom manifold, No. 1, frame 41, while the after connection is made through C. & R. manifold No. 8, located in the port engine room, frames 92 and 93.

The forward secondary drain end connects to C. & R. mani-

fold No. 1, located in forward fireroom, frame 41, and the after end to C. & R. manifold No. 8, in port engine room, frames 92 and 93.

The forward bilge drain, forward trimming-tank drain and chain-locker drains are taken by secondary drain through manifold No. 1, located in forward fireroom, frame 41.

The after bilge drain and after trimming-tank drain are also taken by secondary drain through manifold No. 8, located in port engine room, frames 92 and 93.

There is a 5½-inch connection from bilge well in each fireroom and in each engine room to the secondary drain.

Double Bottom Drain.—The double bottom drain is divided in two sections, each being 4⅜ inches diameter.

The forward section runs aft on the port side from frame 46 to frame 70 and 71 and connects to the C. & R. manifold No. 5, and drains the double-bottom spaces under the fireroom forward of frame 74. It has a connection to C. & R. manifold No. 4, located from frame 55 and 56.

The after portion of this section runs athwartships at frames 69 and 70, and drains wing double bottoms outboard of reserve-feed double bottoms.

The after section runs fore and aft from frame 74 to 89 on the starboard side, and connects with C. & R. manifold 6 and 7, frames 78 and 79; and it drains all double-bottom spaces aft of frame 74, except double bottoms used for reserve-feed tanks.

The double-bottom compartments are flooded through the S. E. manifolds connected to C. & R. manifolds operating the stop-check lift valves in their respective manifolds.

Forward Bilge Drain.—It is 4⅜-inches diameter and drains all double bottoms between 19 and 40 (double-bottom ends at frame 19) and the hold compartments between frames 9 and 19. It connects to C. & R. manifold No. 1, located in forward port firerooms, frames 41, and is drained from there through the secondary drain.

After Bilge Drain.—It is 4⅜-inch diameter and drains all double-bottom compartments between frames 92 and 105 (double-bottom ends at frame 105) and hold compartments be-

tween frames 105 and 113. It connects to C. & R. manifold No. 8, located in port engine room, frames 92 and 93, and is drained from there through secondary drain.

Independent Drain.—These drains come under the cognizance of the Bureau of Steam Engineering. In the firerooms they are 4 inches in diameter and run from the bilge wells to to the fire and bilge pump. These drains are fitted in each fireroom.

The independent drains in engine room are 5 inches in diameter and come under the cognizance of the Bureau of Steam Engineering. They are fitted in each engine room, and drain the bilge wells and shaft alley and engine room. The draining of the shaft alley is to the engine-room bilges, from where there is a direct connection to the Bureau of Steam Engineering manifold, which is connected to the fire and bilge pump.

C. & R. MANIFOLDS.

No.	Frame.	Port or starboard.	Where.
1	41-42	P.	No. 2 fireroom.
2	47	P.	No. 2 fireroom.
3	63	P.	No. 6 fireroom.
4	55	P.	No. 4 fireroom.
5	70-71	P.	No. 8 fireroom.
6	78-79	P.	Port engine room.
7	78-79	S.	Starboard engine room.
8	92-93	P.	Port engine room.
9	97-98	P.	Port engine room.
10	106	P.	Hold, aft.
11	34-35	P.	Upper platform, forward.
12	94-95	C. L.	Upper platform, aft.
13	21-22	S.	Hold, forward.

S. E. MANIFOLDS.

(Not numbered on ship.)

No.	Frame.	Port or starboard.	Where.
14	45-46	P.	No. 2 fireroom.
15	53-54	P.	No. 4 fireroom.
16	62-63	P.	No. 6 fireroom.
17	70-71	P.	No. 8 fireroom.
18	78-79	P.	Port engine room.

No.	Frame.	Port or starboard.	Where.
19	78	S.	Starboard engine room.
20	79-80	P.	Port engine room.
21	79-80	P.	Port engine room.

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS ABOVE W. T. LONGITUDINAL.

Compartment.	Frames.	Side.	Gallons.	Tons. F. W.	Tons. S. W.
A-93	23-28	S.	5,062	18.8	19.4
A-94	23-28	P.	5,062	18.8	19.4
A-95	28-35	S.	8,184	30.4	31.3
A-96	28-35	P.	8,184	30.4	31.3
B-63	40-44	S.	4,335	16.1	16.5
B-64	40-44	P.	4,335	16.1	16.5
B-65	44-48½	S.	5,142	19.1	19.6
B-66	44-48½	P.	5,142	19.1	19.6
B-67	48½-53	S.	5,465	20.3	20.9
B-68	48½-53	P.	5,465	20.3	20.9
B-69	53-57	S.	5,035	18.7	19.2
B-70	53-57	P.	5,035	18.7	19.2
B-71	57-61	S.	5,088	18.9	19.4
B-72	57-61	P.	5,088	18.9	19.4
B-73	61-65	S.	5,735	21.3	21.9
B-74	61-65	P.	5,735	21.3	21.9
B-75	65-70	S.	5,708	21.2	21.8
B-76	65-70	P.	5,708	21.2	21.8
B-77	70-74	S.	5,008	18.6	19.2
B-78	70-74	P.	5,008	18.6	19.2
C-86	74-79	P.	6,111	22.7	23.4
C-87	74-79	S.	6,111	22.7	23.4
C-88	79-87	P.	12,249	45.5	46.8
C-89	79-87	S.	12,249	45.5	46.8
C-90	87-93	P.	8,023	29.8	30.6
C-91	87-93	S.	8,023	29.8	30.6
D-93	93-98	S.	4,819	17.9	18.4
D-94	93-98	P.	4,819	17.9	18.4
D-95	98-100	S.	1,885	7.0	7.2
D-96	98-100	P.	1,885	7.0	7.2
Total, ...			175,698	652.6	671.2

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS BELOW W. T. LONGITUDINALS.

Compartment.	Frames.	Side.	Gallons.	Tons. F. W.	Tons. S. W.
A-97	19-23	P. and S.	6,138	22.2	22.8
A-98	23-28	P. and S.	16,718	62.1	63.9
A-99	28-35	P. and S.	28,106	104.4	107.4
B-79	35-40	P. and S.	27,916	103.7	106.7
B-80	40-43	P and S.	16,987	63.1	64.9
B-81	43-46	P. and S.	17,794	66.1	68.0
B-82	46-48½	P. and S.	15,318	56.9	58.5
B-83	48½-51	P. and S.	15,669	58.2	59.9
B-84	51-54	P. and S.	19,168	71.2	73.2
B-85	54-57	P. and S.	19,490	72.4	74.5
B-86	57-60	P. and S.	19,652	73.0	75.1
B-87	60-63	P. and S.	19,759	73.4	75.5
B-88	63-65	P.	4,119	15.3	15.7
B-89	63-65	S.	4,119	15.3	15.7
B-90	65-70	P.	7,376	27.4	28.2
B-91	65-70	S.	7,376	27.4	28.2
B-92	70-74	P.	6,488	24.1	24.8
B-93	70-74	S.	6,488	24.1	24.8
C-92	74-79	P.	7,807	29.0	29.8
C-93	74-79	S.	7,807	29.0	29.8
C-94	. .	. .	. .	. .	. .
C-95	. .	. .	. .	. .	. .
C-96	79-82	P. and S.	15,587	57.9	59.5
C-97	82-86	P. and S.	20,137	74.8	76.9
C-98	86-89	P. and S.	14,294	53.1	54.6
C-99	89-93	P. and S.	18,091	67.2	69.1
D-97	93-98	P. and S.	22,182	82.4	84.7
D-98	98-100	P. and S.	10,756	39.9	41.1
D-99	100-105	P. and S.	19,882	74.9	76.9
Total, ...			395,224	1,468.5	1,509.2

TRIMMING TANKS—PUMPING AND DRAINAGE.

There are four trimming tanks, two forward and two aft. Those forward are flooded by 5-inch sea connection, frames 7 and 8, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch angle valve, operated at valve and on berth deck in deck plates, frame 7 and 8.

Those aft are flooded by a 5-inch sea connection, frames 114 and 115, port side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch angle valve, operated at valve on berth deck in deck plates, frame 114 and 115.

Draining.—The forward tanks are drained by a 3-inch pipe lead to manifold No. 1, frame 41, and after tanks by a 3-inch pipe lead to manifold No. 9, frame 92 and 93. The extreme forward and after tanks are sluiced into adjacent compartments.

From these manifolds, Nos. 1 and 9, water is handled by secondary drain.

MAGAZINE-FLOODING SYSTEMS.

The following is a general description of the piping of the magazine-flooding systems:

There are two systems—one forward and one aft. Each system floods the magazine spaces in the hold and on the lower platform; the upper platform systems, forward and aft, being supplied by connections to fire main.

Forward System.—It is composed of three separate systems, one on the starboard and two on the port side, each being supplied by an 8-inch sea connection between frame 21 and 22 starboard, and port 35 and 36 port.

Adjacent to the sea connections are 8-inch globe valves on the lower platform, operated at valves and on berth deck in deck plates.

The systems are run below lower platform beam, branches being led up through the deck to the valves in magazine spaces on lower platform and down to valves in hold spaces.

After System.—It is composed of two separate systems one on starboard and one on port side, each being supplied by 8-inch sea connections between starboard frame 100 and 101, and 101 and 102, port. Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valve on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

Upper Platform Systems.—These are connected to the fire main, as described thereunder, and in other particulars have the characteristics of the normal flooding systems.

All magazine flood valves are gate valves, operated at valve and on berth deck in deck plates.

All pipes are of copper, sabined.

All pipe sizes are internal.

Sprinkling Systems.—A sprinkling system is fitted in spaces in hold and magazines excepting shell rooms; it consists of 2½-inch brass pipe, perforated on under side, so that each powder tank can be sprinkled, and is fitted with cut-out valves in each magazine, operated at valve and on berth deck in deck plates. It is connected with the fire system which serves the flooding system on upper platform, and all of which is shown on the plan of the sprinkling system for the forward and after magazines.

All valves are brass gate valves.

DESCRIPTION OF FIRE MAIN.

A fire main of copper, treated by the Sabin process, is worked under the protective deck, nearly the entire length of the ship. The fire main is divided into six systems, viz: starboard and port, forward and after, and forward and after magazine systems, with cut-out valves for each system.

The starboard and port systems are each six inches in diameter and run on each side of the center-line bulkhead below the central ammunition passage throughout the length

of the machinery spaces to the forward and after transverse ammunition passages on upper platform where they are cross-connected; this circuit is connected by a 4-inch riser to the fire and bilge pump in each port boiler room, and by a 5-inch riser to the fire and bilge pump in each engine room. The distiller circulating pump in starboard evaporator room on berth deck can also charge the fire main through a 6-inch connection to this circuit in each dynamo room.

In this circuit there are four valves—Nos. 71 and 72 for forward cross connection and Nos. 101 and 102 for after cross connection—and they are operated either at the valves or on the berth deck in deck plates. The other systems branch from this circuit and are taken from between the cut-out valves in the cross connections mentioned above.

Branches, varying from 2½ inches to 5 inches, depending on their use, are taken from the two systems.

In general all fire plugs are 2½ inches in diameter.

The fire main is by-passed to the flushing main on gun deck between frames 42 and 43 by a 4-inch gate valve.

Valves Nos. 110 and 111, between gun and main decks, cut out supply to ash chutes. Valves Nos. 116 and 117 on the main deck control the ash-chute flushing.

All fire and bilge pumps are protected by 3-inch angle-relief valves set to discharge at 125 pounds pressure.

A 4-inch branch from forward system between frames 13 and 14 connects with the discharge main from flushing pumps, forming a by-pass from fire main to forward flushing system. A 4-inch gate valve at fire main cuts out this by-pass and a D'Este pressure-regulating valve in by-pass at junction with flushing main reduces the fire-main pressure of 100 pounds to 35 pounds before water passes into flushing main.

A 3½-inch relief valve in fire main in crew's lavatory on gun deck, port side, between frames 14 and 15, is set to relieve at 100 pounds and discharges into water-closet trough.

A 2½-inch branch from the riser at frame 112, berth deck, contains a relief valve set at 100 pounds, which discharges into scupper on the port side between frames 114 and 115.

The magazine fire systems lead to forward and after magazines on upper platform, which cannot be flooded from sea.

A 5-inch branch taken from the forward cross connection in the starboard passage on the upper platform, supplies the floods in forward magazines.

A 5-inch gate valve, No. 67, between frames 31 and 32, cuts out the forward magazine system.

A 5-inch branch taken from the after cross connection, starboard side of vestibule on upper platform at frame 94, supplies the after magazine floods.

A 5-inch gate valve, No. 103, on after side of bulkhead 94½, cuts out the after magazine system. These cut-outs, Nos. 67 and 103, are operated at valves and on berth deck in deck plates.

Fire plugs, No. 5 in forward handling room and No. 6 in after handling room on lower platforms, are supplied from forward and after magazine-flooding systems, respectively.

DECK DRAINS.

The officers' showers and baths, and firemen's and servants' washrooms on gun deck, are drained through 3-inch, 4-inch and 3-inch pipes, respectively, led up to gun-deck beams, port side near center line, and discharging overboard through ship's scuppers, at frame 46 and 47, and a special scupper, at frame 80 and 81, port and starboard.

All other plumbing spaces are fitted with independent drains, with the exception of galleys and general mess pantries, which drain through ship's scupper, frame 46 and 47, port and starboard. The crew's showers on gun deck drain into ship's scuppers, frame 12 and 13, port side only.

FRESH-WATER SYSTEM.

A fresh-water main of galvanized wrought iron, in general of 3 inches in diameter, runs the length of the ship and is supplied either by the two electric fresh-water pumps or from two 1,000-gallon gravity tanks on upper deck, the forward one at frame 41, the after one between frames 85 and 86.

Three-inch risers from the fresh-water main to forward and after gravity tanks serve as filling and discharge pipes for tanks, at frames 41 and 85, where these tanks are located. From frame 41 to 71½ this 3-inch main follows along the center line of the ship through the wash rooms on gun deck. From 71½ to 85½ it runs in the berth-deck passage and machine shop.

At frame 41 on gun deck the forward 2½-inch line turns outboard to starboard, passing through the bakery and crew's space to a point between frames 28 and 29 where it drops to berth deck. Here it follows the passage to bulkhead 20, where it passes down to protective-deck slope, runs forward to bulkhead 14, rises again and connects to filling pipe from ship's side on berth deck. This in turn is connected to pump and tanks on upper platform through a 2½-inch branch dropped near center line at frame 15.

The after 2½-inch line starts at frame 85½, in workshop on berth deck, runs aft to passage, where it turns outward to port, passing down to protective deck just forward and transverse-armored bulkhead, frame 95. From this point it follows along the protective-deck slope to frame 110, where it turns down through protective deck to upper platform and connects to pump and to tanks on lower platform and in hold.

These 2½-inch lines also serve as filling pipes to tanks, being by-passed at pump in steering-engine flat to top of tanks in hold and direct connected to top of tanks forward on upper platform.

Discharges from pumps are 2½ inches in diameter. Cut-out valves are fitted near tanks in all filling and suction pipes.

Check valves are fitted where necessary.

Suction pipes also act as equalizers. 1½-inch drain valves are fitted in suctions from tanks.

Two-inch overflow pipes are fitted to all tanks in hold; 3-inch overflow pipes are fitted to gravity tanks.

Tanks below protective deck are filled from dock or water boat through 2½-inch hose connections, starboard and port, at ship's side, under gun deck, between frames 13 and 14.

Filling pipes from ship's side, starboard and port, between frames 73 and 75, berth deck, to reserve-feed tanks are by-passed in berth-deck passage to fresh-water main, and may be used for filling tanks in hold.

Branches from the distiller line forward are arranged to fill, through two-way cocks, the copper tanks located on main deck for firemen's, petty officers' and servants' washrooms and those in laundry, these being the only rooms supplied with small tanks.

Two 2-H.P. electric pumps, having a capacity of 60 gallons per minute each, are provided for supplying the fresh-water main and filling the gravity tanks on upper deck from the tanks below protective deck. One electric pump is located on the upper platform just forward of bulkhead 19, and is arranged to draw only from forward tanks, discharging into fresh-water main and filling tanks above protective deck. The other electric pump is located in steering-engine compartment and is arranged to draw *only* from tanks aft, discharging into main and filling all other fresh-water tanks.

One and one-half-inch relief valves on pump discharges protect the pumps. The forward is set to relieve at 21 pounds pressure and after one at 26 pounds.

A 1½-inch hose valve on superstructure just above main deck, port side, frame 37, supplies steam launches with fresh water.

Branches from main supply all spaces requiring fresh water, such as lavatories, bath rooms, wash rooms, dispensary, operating room, pantries, galleys, bakery and laundry, also water butts and ice machine.

Three-quarter-inch faucets, for bucket use, are fitted in seamen's head, firemen's washroom, and for stateroom use, in athwartship passage on bulkhead 80, berth deck.

All fixtures are supplied direct from fresh-water main, except those in firemen's, petty officers' and servants' washrooms and laundry. These are supplied from cooper tanks.

All branches have cut-out valves at or near the main.

CAPACITIES OF WATER TANKS.

Compt.	Frame.	Location.	Side.	Capacity.		
				Gallons.	Tons S. W.	Tons F. W.
		FRESH WATER.				
A-31	14-19	Upper platform	Port	1,640	...	6.09
A-31	14-19	Upper platform	Starboard	1,640	...	6.09
A-31	14-19	Upper platform	Port	1,904	...	7.07
A-31	14-19	Upper platform	Starboard	1,904	...	7.07
D-4	105½-110	After hold	Both	2,804	...	10.05
D-13	105-110	Lower platform	Port	1,418	...	5.29
D-13	105-110	Lower platform	Starboard	2,708	...	10.10
D-13	105-110	Lower platform	Port	2,708	...	10.10
...	41	Upper deck	Gravity tank	990	...	3.67
...	85	Upper deck	Gravity tank	990	...	3.67
			Total, - -	18,706	...	69.65
		RESERVE FEED WATER.				
B-94	63-65½	Double bottom	Port	4,129	15.7	15.3
B-95	63-65½	Double bottom	Starboard	4,129	15.7	15.3
B-96	65½-70	Double bottom	Port	7,420	28.4	27.6
B-97	65½-70	Double bottom	Starboard	7,420	28.4	27.6
B-98	70-74	Double bottom	Port	6,493	24.8	24.1
B-99	70-74	Double bottom	Starboard	6,493	24.8	24.1
C-94	74-79	Double bottom	Port	7,764	29.6	28.8
C-95	74-79	Double bottom	Starboard	7,764	29.6	28.8
			Total, . .	51,612	197.0	191.6
		TRIMMING.				
A-1	1-5	Hold	Both	4,959	18.94	18.42
A-2	5-9	Hold	Both	4,997	19.08	18.56
D-6	113-116	Hold	Both	9,208	35.17	34.19
D-7	116-120	Hold	Both	8,228	31.43	30.56
			Total, . .	27,392	104.62	101.73

SALT-WATER SYSTEM.

A flushing main of copper, 4 inches in diameter, treated by the Sabin process, runs parallel with and close to the fresh-water main between frames 42 and 76. Branches from this portion supply the servants', firemen's and petty officers' washrooms on gun deck and laundry, galleys and general-mess pantry on main deck.

At frame 76 this reduces from 4 inches to 3 inches, and this size continues to the general workshop, where it divides into three 2-inch branches. Two of these branches turn outboard, one to starboard and the other to port, and supply salt water

to the wardroom officers' watercloset and junior and warrant officers' watercloset, respectively, on gun deck.

The third branch continues aft along the berth deck, turning outboard to starboard, and drops to the protective deck at frame 95. From this point the flushing line follows along the protective-deck slope to bulkhead 119, reducing to 1½ inches at frame 104.

This after branch supplies all the pantries and the captain's bath with salt water.

A 1½-inch riser from the main between frames 86 and 87 supplies the wardroom, junior and warrant officers' lavatories and baths on gun deck.

This flushing main is charged by the distiller circulating pumps in the evaporator rooms on berth deck, which are cross connected between frames 75 and 76. The forward and after portions of the flushing main branch from this cross connection in berth-deck passage, and are fitted with cut-out valves at their junction with the cross connection.

A 3-inch relief valve, set at 20 pounds, on cross connection in port evaporator room, protects the pumps.

A 4-inch gate valve, No. 109, between frames 42 and 43 on gun deck, permits charging the flushing main directly from the fire main.

Spaces forward of the forward transverse armored bulkhead are flushed by an independent system.

Two electric salt-water centrifugal pumps on upper platform, between frames 12 and 14, take water through a 4½-inch riser to flushing main in crew's washroom on gun deck.

This independent system supplies salt water to crew's washroom and showers, and the petty officers' watercloset on gun deck and sick-bay bath on berth deck. A 2-inch branch runs to ice machines on berth deck and supplies circulating water for compressors.

A 4-inch gate valve, No. 66, just forward of bulkhead 14 on upper platform, permits charging this flushing main from fire main when electric pumps are cut off. A D'Este pressure-

regulating valve, set at 35 pounds, in by-pass from fire main to flushing main, prevents a drop in fire-main pressure when by-pass valve No. 66 is opened.

A 3-inch relief valve in crews' head, starboard side, near bulkhead 18, set at 35 pounds, discharges into watercloset trough.

Three-quarter-inch faucets for bucket use are fitted in crew's and firemen's washrooms.

All branches taken from flushing main have cut-out valves at or near the main.

No salt-water tanks are fitted on the ship.

Two valve manifolds are on upper platform at bulkhead 35, port side, in transverse passage, and on the other on centerline at bulkhead 94 in vestibule, have connections from sea and bilge, and are designed for use with 6-inch handy-billy pump.

In addition, circulating water for ice machines is taken from a special 3-inch sea connection on lower platform, starboard side, between frames 22 and 23. The discharges overboard are through ship's scuppers.

OFFICIAL TRIALS.

The official trials of the machinery of the *Montana* consisted of three parts, as follows:

STANDARDIZATION.

For the purpose of standardizing the screws of this vessel fourteen runs were made over the standard-mile course off Rockland, Me., on April 1, 1908. The sea was moderately rough from the northward, and the wind was moderate to a fresh breeze from the north by west to north.

The mean draught of this vessel was 25 feet and ½ inch, the trim being 7⅞ inches by the stern, and the displacement was 14,537 tons.

POWER AND SPEED ON STANDARDIZATION.

Number of runs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Indicated horsepower:														
Starboard engine	4,881	4,948	4,993	8,131	8,000	8,337	13,055	12,945	12,634	13,348	13,762	10,748	10,802	10,553
Port engine	4,440	4,272	4,742	7,675	6,952	7,745	12,913	12,830	13,323	13,282	13,106	9,998	10,340	10,372
Total, both engines	9,321	9,220	9,735	15,806	14,952	16,082	25,968	25,775	25,957	26,630	26,868	20,746	21,142	20,925
Engine auxiliaries	218	215	217	249	239	252	358	432	428	444	438	405	373	373
Other auxiliaries	230	254	236	229	228	374	529	545	567	543	445	372	376	371
All machinery	9,769	9,689	10,188	16,284	15,419	16,708	26,855	26,752	26,952	27,617	27,751	21,523	21,891	21,669
Speed, knots	17.086	15.859	17.241	18.938	19.324	19.210	22.332	21.556	22.388	21.608	22.842	20.168	21.844	19.955
Mean revolutions	88.48	85.86	89.27	102.66	101.40	103.65	120.71	120.08	120.29	120.84	122.39	112.28	113.09	112.65

AUXILIARIES—REVOLUTIONS OR DOUBLE STROKES.

Number of run or observation.	Pumps, starboard.						Pumps, port.					Pumps.		Dynamo engines.	Forced-draft blowers.
	Main air.	Main circulating.	Main feed, outboard.	Main feed, inboard.	Fire and bilge.	Auxiliary condenser.	Main air.	Main circulating.	Main feed, outboard.	Main feed, inboard.	Fire and bilge.	Distiller circulating.	Starboard dynamo condenser.		
1	24	165	9	9	50	50	24	170	13	13	50	8	48	350	132
2	26	150	9	7	46	46	23	176	12	12	50	8	50	...	178
3	24	159	8	9	47	48	23	179	10	10	52	8	48	...	151
4	24	155	14	11	38	51	20	165	16	16	50	8	50	...	106
5	24	141	17	14	37	51	24	160	13	13	48	8	46	...	103
6	24	154	17	15	40	56	22	160	14	14	50	8	48	...	346
7	30	180	25	21	32	44	21	172	24	24	52	10	50	...	445
8	32	189	22	23	30	45	20	186	33	33	50	9	48	...	454
9	32	192	27	28	25	37	21	184	27	27	50	9	48	...	465
10	30	198	30	28	25	38	20	188	27	27	48	8	50	...	450
11	35	194	29	29	24	62	20	190	26	26	50	6	48	...	404
12	38	198	26	18	26	60	21	184	26	26	48	6	48	...	348
13	38	204	23	18	27	70	20	180	21	21	50	6	48	...	349
14	39	188	22	18	27	74	20	187	23	23	48	6	50	...	344

FOUR-HOUR FULL-POWER RUN.

Engine.	Revolutions per minute.	Steam pressure.					Mean effective pressure.					Cut-off in cylinders in decimal of stroke.				Vacuum, inches.	Barometer, inches.
		In boilers, per gauge.	At engine, per gauge.	H.P. steam chest gauge.	I.P. receiver, absolute.	L.P. receiver, absolute.	H.P. cylinder.	I.P. cylinder.	F.L.P. cylinder.	A.L.P. cylinder.	Referred pressure.	H.P.	I.P.	F.L.P.	A.L.P.		
Starboard.	122.93	...	262	245	113	40	106.8	51.2	21.1	21.4	54.23	86	.736	Vari	able	25.2	
Port	122.25	...	266	251	118	38	110.3	52.9	19.6	20.1	54.11	86	.736	Vari	able	25.2	
Average	122.589	271	264	248	116	39	108.6	52.1	20.4	20.8	54.17	86	.736	Vari	able	25.4	

......	Auxiliaries. Revolutions or double strokes.											Air pressure (fire-room) in. of water.	Temperature.						
	Main air pump.	Main circulating pump.	Main feed pump.	Auxiliary feed pump.	Hotwell pump.	Sanitary pumps.	Fire and bilge pumps.	Water service pumps.	Aux. condenser pumps.	Dynamo engines.	F.D. blowers.		Injection.	Discharge.	Hotwell.	Feed.	Smoke-pipe gases.	Engine-room work level.	Fireroom work level.
Starboard.	36	187	29	...	...	...	42	...	66	350	377	1.19	38	111	76	153	605	69	76.3
Port	25	198	27	...	...	...	72	...	...	350	...	1.19	38	69	71	...	605	...	76.3
I.H.P	33	137	279	...	...	...	11	...	6	118	200	Total I.H.P. (auxiliaries) 791							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Wa
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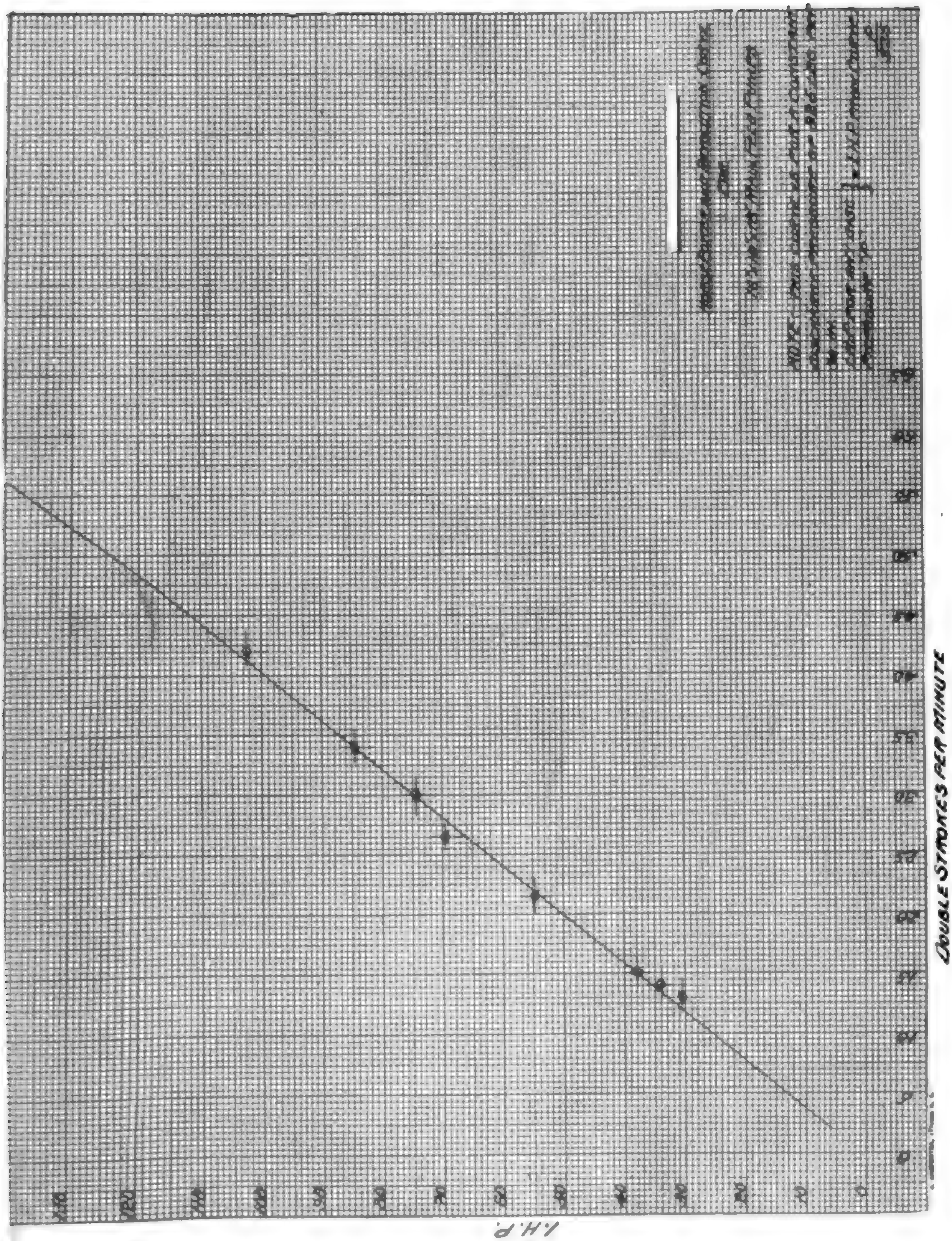
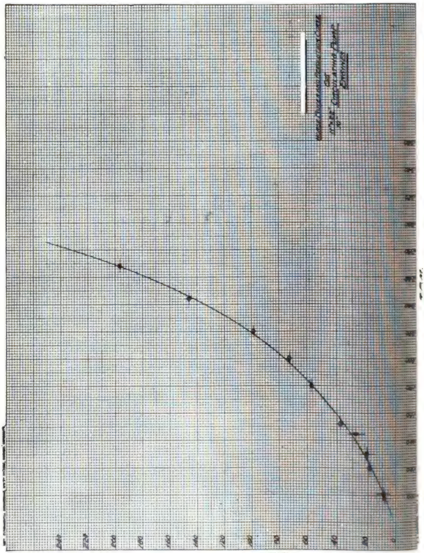
Nos.
Nos.
Nos.
Nos.
4-H
85


DOUBLE STROKES PER MINUTE
I.H.P.


Horse Power and Revolution Curve
of
17.25"/16" Circulating Pump
Engines
I.H.P.
0
20
40
60
80
100
120
140
160
180
200
224
240
R.P.M.

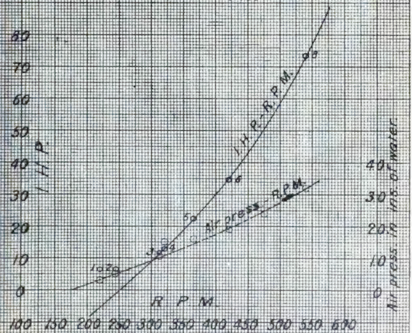
U. S. S. MONTANA.

Horse Power and Revolution Curve.

$\frac{6\times6}{6}$ Blower Engine.

Card No.	R.P.M.	Steam Press	Air Press	I.H.P.
1	220	155	0.3	6.31
2	244	155	0.5	6.47
3	312	150	1.05	11.70
4	320	160	1.5	12.72
5	365	150	1.6	22.11
6	420	150	1.9	34.68
7	475	158	2.4	*
8	540	155	3.2	73.48

*Indicator card broke.



U.S.S. MONTANA.

INDICATOR CARDS FROM ELECTRIC PLANT.

INDICATOR CARDS FROM DYNAMO ENGINES.

138.6 I.H.P. EACH, UNDER TRIAL CONDITIONS.

H.P. CYLINDER.

SCALE OF SPRING	80#
M.E.P.	61.6#
R.P.M.	340
I.H.P.	80.9
STEAM PRESSURE	150#
VACUUM	6"
VOLTS	125
AMPERES	665

L.P. CYLINDER.

SCALE OF SPRING	40#
M.E.P.	[illegible]
R.P.M.	340
I.H.P.	[illegible]

INDICATOR CARD FROM DYNAMO AIR AND CIRCULATING PUMPS.

4.46 I.H.P. EACH, UNDER TRIAL CONDITIONS.

SCALE OF SPRING	80#
M.E.P.	66.4#
DOUBLE STROKES PER MINUTE	40
I.H.P.	4.46
STEAM PRESSURE	160#
VACUUM	6"

FOUR-HOUR FULL-POWER RUN.

The four-hour full-power trial began at 6·03 P. M., April 4, 1908, and continued until 10·03 P. M. that same day. The sea was rough and the wind was a fresh breeze from northwest increasing to a moderate gale from north-northwest. The compass course steered was southwest ½ west, to south ½ west.

The mean draught of the ship was 25 feet and $\frac{7}{16}$ inch, the trim being 1⅜ inches by the stern, and the displacement being 14,531 tons.

DATA OF FOUR-HOUR FULL-POWER FORCED-DRAFT PRELIMINARY TRIAL.

	Starboard.		*Port.*
Maximum average revolutions per minute for fifteen-minute period	124.40		123.93
Average revolutions per minute, four hours	122.93		122.25
Mean revolutions per minute, both engines		122.589	
Maximum steam pressure at boilers, in pounds		275.7	
Average steam pressure at boilers, in pounds		271.0	
engines, in pounds	262.0		266.0
H.P. steam chest	245.0		251.0
Maximum air pressure in fireroom		1.47	
Average air pressure in fireroom		1.19	
Maximum vacuum, each engine	25.5		25.8
Average vacuum, each engine	25.2		25.5
Collective I.H.P. of all main engines		27,489.0	
main engine, air, circulating, feed and hotwell pumps		27,938.0	
main and all auxiliary engines in operation during trial		28,280.0	
Kind and quality of coal used on trial		Nuttleberg hand-picked.	
Average pounds of coal used during trial, per hour		57,792.0	
Pounds of coal per hour used by main and all auxiliary engines in operation during trial, per I.H.P.		2.044	
Pounds of coal used per hour by main engines, air, circulating, feed and hotwell pumps, per square foot grate surface		36.35	
Pounds of coal per hour used by main engines alone		2.102	
Draught at beginning of trial, forward, feet and inches		25-01⅛	
aft, feet and inches		25-02⅝	
Mean draught at beginning of trial, feet and inches		25-01$\frac{13}{16}$	
Corresponding displacement at mean draught at beginning of trial, tons		14,615.0	
Draught at end of trial, forward, feet and inches		24-07¼	
aft, feet and inches		25-03¼	

	Starboard.		*Port.*
Mean draught at end of trial, anchor down, feet and inches		24-11¾	
Mean draught at end of trial, anchor up, feet and inches		24-11½	
Corresponding displacement at mean draught at end of trial, tons		14,475.0	
Corresponding displacement at mean draught during trial, tons		14,531.0	
Speed of ship, in knots per hour		22.26	
Slip of propellers in percentum of their own speed	15.72		15.25

TWENTY-FOUR-HOUR TRIAL.

The twenty-four-hour trial, which was run at two-thirds power, began at noon on April 5, 1908, and finished at noon on April 6, 1908. The sea was smooth to moderate, the wind being gentle to fresh breezes from northwest to south. Various courses were steered.

The mean draught of the ship was 24 feet 1 inch, the trim being 14⅝ inches by the stern, and the displacement was 14,458 tons.

DATA OF TWENTY-FOUR-HOUR FULL-POWER FORCED-DRAFT PRELIMINARY TRIAL.

	Starboard.		*Port.*
Maximum average revolutions per minute for one-hour period	113.45		113.37
Average revolutions per minute, twenty-four hours	109.90		109.74
Mean revolutions per minute, both engines		109.82	
Maximum steam pressure at boilers, in pounds		271.0	
Average steam pressure at boilers, in pounds		248.0	
engines, in pounds	240.0		237.0
H.P. steam chest	204.0		211.0
Maximum air pressure in fireroom		0.79	
Average air pressure in fireroom		0.55	
Maximum vacuum, each engine	26.4		25.8
Average vacuum, each engine	26.0		25.4
Collective I.H.P. of all main engines		19,102.0	
Collective, main engine, air, circulating, feed and hot-well pumps		19,427.0	
Collective, main and all auxiliary engines in operation during trial		19,688.0	
Kind and quality of coal used on trial		Nuttleberg hand-picked.	
Average pounds of coal used per hour during trial		36,950.0	
Pounds of coal per hour used by main and all auxiliary engines in operation during trial, per I.H.P		1.877	

	Starboard.	Port.
Pounds of coal per hour used by main engines, air, circulating, feed and hotwell pumps, per square foot grate surface	23.24	
Pounds of coal per hour used by main engines alone	1.934	
Draught at beginning of trial, forward, feet and inches	24–6¼	
aft, feet and inches	25–8⅝	
Mean draught at beginning of trial, feet and inches	25–01 $\frac{7}{16}$	
Corresponding displacement at mean draught at beginning of trial tons*	14,597.0	
Draught at end of trial, forward, feet and inches †	24–00⅜	
aft, feet and inches †	25–05⅝	
Mean draught at end of trial, feet and inches †	24–09	
Corresponding displacement at mean draught at end of trial (actual), tons	14,210.0	
Corresponding displacement at mean draught during trial, tons	14,458.0	
Speed of ship, in knots per hour	13.75	13.26
Slip of propellers, in percentum of their own speed	20.48	

The working of the machinery, both main and auxiliary, and the performance during the standardization, the four-hours full-power forced-draft, and the twenty-four-hours endurance trials, was satisfactory with the exception of minor defects, such as the unsatisfactory working of throttle valves and the defective and leaky tube in boiler N, and two defective and leaky tubes in boiler Q.

In running the five high-speed runs on the standardization trials, with the maximum pressure in high-pressure steam chest as allowed, it was found necessary, in order to obtain the contract speed of 22 knots, to by-pass live steam into the first and second receivers, as it was not possible to obtain the required speed with all steam passing through high-pressure cylinder swith the valves as set.

The contractors finding that, on the five high-speed runs of the standardization trial with boilers and machinery working satisfactorily, they could only obtain a slight margin of speed above the contract requirement with the high-pressure valves as set and live steam into the receivers, requested the Department to grant them permission to reset the high-pressure

* 109 tons of water ballast added after reading draught.

† Water brackish ; density measured by hydrometer.

Engines.	Revolutions per minute.	Steam pressure.					Mean effective pressure.					Cut-off in cylinders, in decimal of stroke.				Vacuum, inches.	Barometer, inches.
		In boilers, per gauge.	At engine, per gauge.	In H.P. steam chest, gauge.	I.P. receiver, absolute.	L.P. receiver, absolute.	H.P. cylinder.	I.P. cylinder.	F.L.P. cylinder.	A.L.P. cylinder.	Referred pressure.	H.P.	I.P.	F.L.P.	A.L.P.		
Starboard..	109.90	...	240	204	88.6	34.4	92.4	36.35	17.90	17.10	42.87	.756	.725	.608	.608	26.0	...
Port.........	109.74	...	237	211	90.0	31.2	92.5	38.60	14.70	15.72	41.75	....	...Vari	able...	....	25.4	...
Average....	109.82	248	239	207	89.3	32.8	92.4	37.48	16.30	16.41	42.31	....	...Vari	able...	....	25.7	...

...	Auxiliaries. Revolutions or double strokes.											Air pressure (fireroom), inches water.	Temperature.						
	Main air pump.	Main circulating pump.	Main feed pump.	Auxiliary feed pumps.	Hotwell pumps.	Distributing circ. pumps.	Fire and bilge pumps.	Water service pumps.	Aux. cond. pumps.	Dynamo engines.	F.D. blowers.		Injection.	Discharge.	Hotwell.	Feed.	Outside air.	Engine-room work level.	Fireroom work level.
Starboard..	24.0	163.8	20.7	...	...	75	55.9	...	57.6	...	...	.55	42	100	72	168	55	73	84
Port.........	22.8	160.7	21.7	...	...	75	64.7	...	44.6	344	287	.55	42	95	65	...	55	73	84
I.H.P.......	25.0	83.0	21.7	...	...	3	18.0	...	11.0	118	80	Total I.H.P. (auxiliaries)............586							

valves so that all steam could be passed through the high-pressure cylinder, in this way economizing steam and securing a better distribution of power among the different cylinders. This request was granted, and during the four-hours and twenty-four-hours trials all steam that was used in the engines was passed through the high-pressure valves.

It was very noticeable that the engines worked more smoothly and satisfactorily when passing all steam through the high-pressure cylinders than when live steam was introduced into the receivers direct, and the power was much more equally distributed.

It was the opinion that with the machinery and boilers located in compartments isolated by athwartship bulkheads in which there are no doors for communication, it would be very difficult to maintain a proper supervision of the routine work and repairs while in port and a proper supervision of the machinery in the compartments while steaming at sea during protracted cruising, especially in peace times, when the complement of men allowed the vessel is small in comparison to what it would be during a war period.

The doors that the contractors considered necessary and that the Department allowed them to install in the athwartship watertight bulkheads for use in case of emergency, were kept sealed during the trials, with the exception of the two short periods of time on the twenty-four-hours trial, in which a tube burst in boiler N and two burst in boiler Q. At these short periods, of only a few minutes each, the seal placed on the door leading from the forward end of the engine room on the port side to the after port fireroom was broken in order to allow a communication from the port engine room to the after port fireroom.

The contractors installed two 2-inch temporary pipes from the main steam pipes to the first and second receivers, which were used only during the standardization trials for admitting live steam to the receivers. These were used in lieu of the larger by-pass pipes as originally installed.

During none of the trials was water used on any of the bearings other than that ordinarily used through the bearings.

During the twenty-four-hours trial at not less than two-thirds of the indicated horsepower as developed by main engines (and near the end of the trial), one 2-inch tube split in boiler N and two 2-inch tubes in boiler Q, the defect occurring in each case in the first pass. An examination of the defective tubes showed that there was a split in each due to laminations in the tube material, and that the lamination extended through the entire length of the tube. To facilitate the removal of the defective tube in boiler N, and because there was considerable bulge at the point of rupture, a tube in which there was no defect was removed.

An examination of the interior of the good tube removed, showed in spots excessive deposits of hard mill scale.

INSPECTION AFTER TRIAL.

a. Removed all main valves of main engines, examined valves and rings and found same in good condition.

b. Examined all main cylinders and found same in good condition.

c. Raised followers and examined all rings of main pistons.

d. Stripped P.I.O. and P.F.L.P., S.I.P. and S.F.L.P. crossheads and found caps and bearings in good condition.

e. Lifted P., Nos. 2 and 4, and S., Nos. 1, 5 and 6, crank-shaft caps and found caps and bearings in good condition.

f. Stripped S.F.L.P. and S.I.P. and P.H.P. and F.A.L.P. crank pins and found same in good condition.

g. Opened main and auxiliary condensers and filled fresh-water side with water. There was no leakage of tubes, and everything was satisfactory as far as could be examined, with the exception of a small amount of grease contained in shell of condenser. It is recommended that the condensers be cleaned before vessel is delivered to Government.

h. Examined steam and water ends and valve-chest chambers of main feed pumps and found same in good condition.

i. Examined steam and water ends and valve-chest chambers of main air pumps and found same in good condition.

j. Opened steam cylinders of circulating-pump engine and found same in good condition.

k. Examined steam and water cylinders and valve-chest chambers of one fire and bilge pump and found same in good condition.

l. Removed section of main steam pipe in No. 2 starboard fireroom. Pipe was entirely free from grease and in good condition.

m. Stripped blower in No. 3 fireroom for examination and found same in good condition.

n. Examined steam and water ends and valve-chest chambers of one auxiliary feed pump in firerooms and found same in good condition.

Boilers.—Examined interiors of drums, furnaces and fittings, interior of a number of 4-inch and 2-inch tubes selected at random, and also inboard sideboxes of all boilers except K and M. Boiler K was in use for auxiliary purposes; M was being prepared to raise steam; both of the latter boilers were thoroughly examined a few days prior to the inspection of the Board by the Inspector of Machinery at contractors' works.

Furnaces.—The furnaces were found in good condition except all brick work, furnace doors, liners and cheek pieces.

The 4-inch tubes above furnaces were straight-edged and found generally to bow upward. The maximum bend was about one-half inch from horizontal; usually the greatest bend did not exceed five-sixteenths of an inch; a few of the tubes were straight.

Drums.—The interior of drums was free from grease and scale, and inside fittings were in good condition.

Tubes.—The interior of the tubes (both 4-inch and 2-inch) showed no evidence of grease. There was some deposit of mill scale in all tubes, and as well in sideboxes.

THE TURBINE AND RECIPROCATING ENGINE A COMBINATION FOR BETTER ALL-AROUND EFFICIENCY IN VESSELS OF WAR.

By Lieut. H. C. Dinger, Member.

The question of whether the turbine or the reciprocating engine shall be installed in large fighting vessels is still argued pro and con in many services, and in the United States Navy we find the champions of both designs. There has been for some time past considerable contention between the advocates of these two systems of propulsion, and the claims of each type are being ardently set forth from time to time.

Each type of machine presents certain great advantages on one hand and certain defects on the other. The turbine gives greater economy at high speed, slight decrease in weight, does not require as much height of engine-room space, but generally requires as much or even greater floor space. Reversing presents considerable difficulties in that special arrangements and a series of backing turbines must be provided.

For slow speeds at reduced power the marine turbine is not economical, not nearly as economical as the reciprocating engine. By fitting special cruising turbines, a considerable improvement in economy is secured, but even with these added fittings the steam consumption at low speeds is unsatisfactory. A battleship will do but a very small percentage of her steaming at high speed. Ninety per cent. of the steaming will be at speeds not above 12 knots, and with this condition present, economy at these reduced powers should be a most weighty factor in deciding upon the type of machinery.

The reciprocating engine is easily handled, reversing is

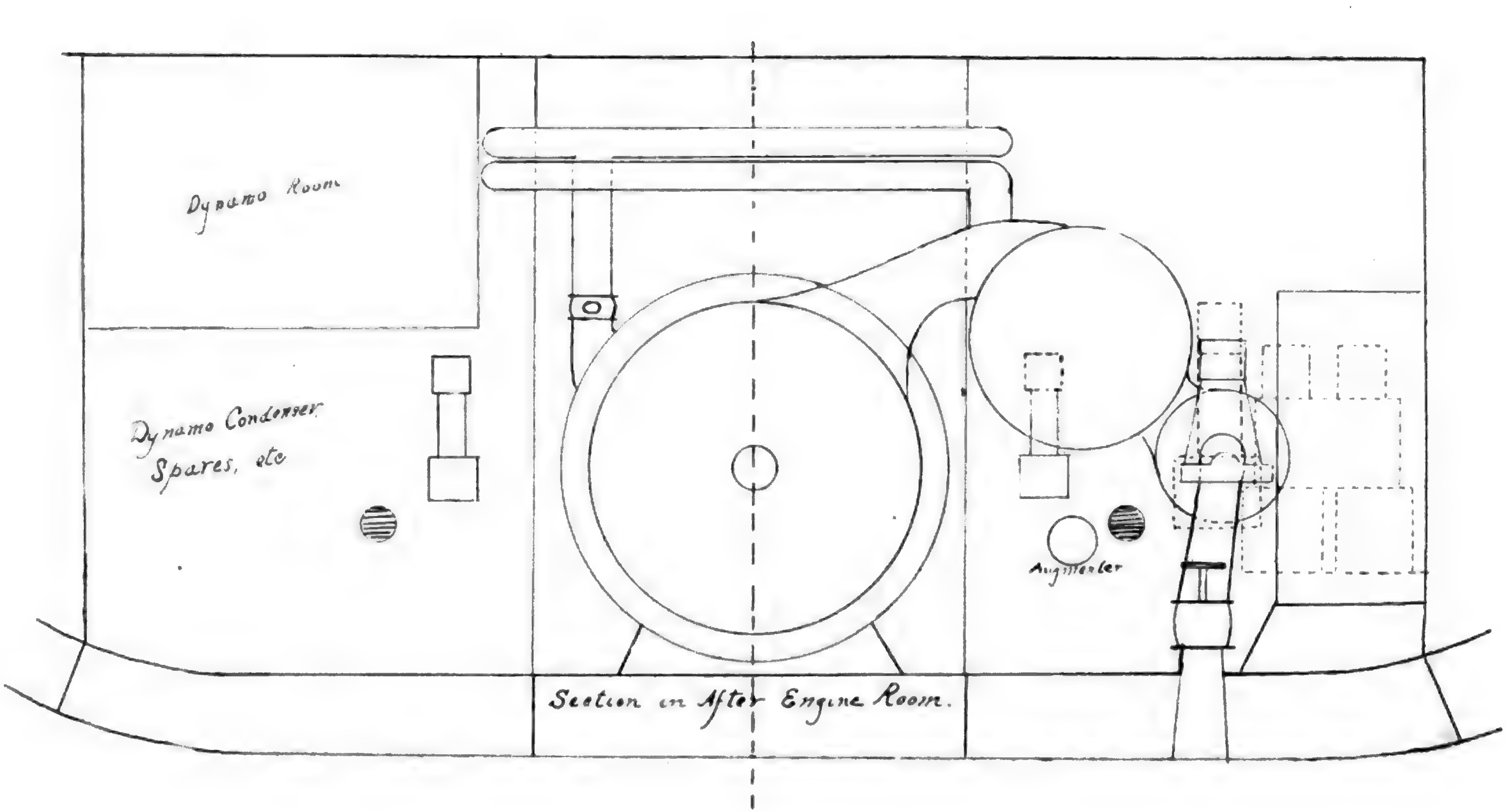
readily accomplished. It is economical at low powers, is well known and understood and is thoroughly reliable. It gives greater propeller efficiency at practically all speeds. At high speeds it is not quite as economical as the turbine. It requires more oil and attendance and is probably somewhat heavier than the turbine.

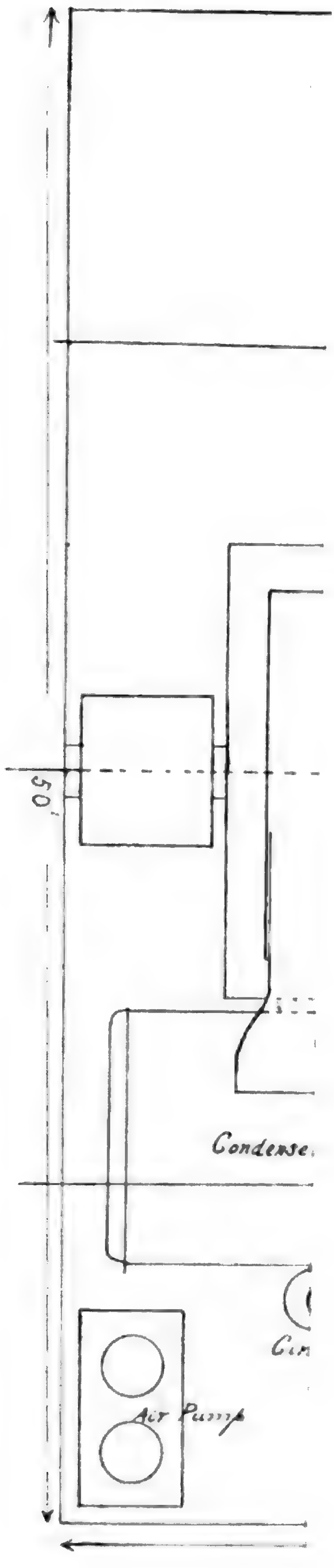
One of the prime requisites of a battleship is ability to maneuver. Anything that detracts from this important feature must be looked upon with more or less suspicion. With turbines the ship cannot be maneuvered as readily or as directly as it can when fitted with reciprocating engines. Some types of turbines are much better than others in this respect, but they are all well behind the reciprocating engine when it comes to handling a vessel at close quarters, stopping, turning, backing, etc.

Now for one condition, cruising speeds, the reciprocating engine is better, and for another condition, full speed, the turbine is the better. But the machinery of a man-of-war must meet both of the conditions satisfactorily. Can a combination be effected that will allow us to use the advantages of each in its place? Let us see.

Let us propose to put the total power of a first-class battleship, 20,000 I.H.P., into three units, one on each of three shafts. The center shaft to have a turbine engine of about 12,000 I.H.P. and each of the wing shafts to have a reciprocating engine of about 4,000 I.H.P.

The general arrangement, using the same space as is now used for twin-screw reciprocating engine, will be approximately as shown in sketch. The weight will be about the same for the same total power, perhaps somewhat less than either the all-turbine or the all-reciprocating engine arrangement (for reasons spoken of later.) The reciprocating engines are to have 4,000 I.H.P. each, and would be of the latest design of three cylinder, triple-expansion type; about $\frac{22 \times 34 \times 62 \text{ inches}}{48 \text{ inches}}$. The engine should be fitted for forced lubrication, and by having this would be placed more nearly


Dynamo Room
Dynamo Condenser
Spares, etc
Aug Heater
Section in After Engine Room.



50'
Condense
Air Pump

on a par with the turbine in the matter of care in operation. They would be used alone in all cases where the speed is not over about 14 knots, which speed would require about 7,000 I.H.P. The reciprocating engines would be placed in two engine rooms, as shown in sketch. The turbine would be fitted to the center shaft; it would be fitted for going ahead only, and primarily designed for the conditions of full power. The propeller for the turbine would be designed especially for full speed, and in this condition could give better results than one designed to operate at various speeds. The propellers of the reciprocating engine might be designed to operate at their greatest efficiency at medium speeds. At very low speeds the propeller of the center shaft could be uncoupled and allowed to revolve. The loss from this drag would be very slight. It would not even be necessary to uncouple the turbine, since the whole rotor could be allowed to revolve idly. Whatever loss would be due to the revolving of this idle screw would be more than made up by the increased efficiency of the reciprocating engine and its propeller.

The turbine on the center shaft could be designed and installed to meet the conditions of going ahead only. There would be no need of any arrangements of backing or cruising turbines and the weight of these appendages would be saved. There would also be no need of trying to adjust the design to get economy with the turbine at low and greatly varying powers. Thus, further reductions of weight might be possible. The turbine shaft, being in the center, will give the greatest possible room for installing a rotor of large diameter. The whole combination allows for a very compact arrangement, as can be seen from the sketch.

Though the exact space required would depend on just what design of turbine was used, it would be possible in practically all types to place the turbine directly between the ends of the reciprocating engines, as shown in sketch. By doing this considerable fore-and-aft space is saved. The location of the auxiliaries is indicated in a general way and

the suggested arrangement gives fully as ample room as that available in our latest design using reciprocating engines. The space is 50 feet in length and 50 feet in width, and this is considerable less in length than what has been used for the same purposes in the twin-screw reciprocating-engine arrangement for 16,500 I.H.P. In the *Connecticut* design a length of about 60 feet is used, though this includes some bunker space. If the same length, 60 feet, is used there will be correspondingly more room for the combination arrangement. On the *Delaware* class, with 25,000 I.H.P. and all-turbine arrangement, a space 51 feet athwartship and 60 feet in length is to be used.

ADVANTAGES SECURED.

If it is assumed that the turbine gives an increase of 10 per cent. in economy over the reciprocating engine at full speed (an assumption less than the turbine advocates claim and somewhat more than the turbine has, as yet, done in practice) we would, in the proposed arrangement, have an increase in economy of 6 per cent. over the reciprocating arrangement at full speed. At one-fourth or one-third power, which would be the cruising speed of the vessel, the turbine, as now developed with cruising turbines and other refinements, may be assumed to use 30 per cent. more steam than the reciprocating engine (the difference is very likely to be even greater than this). So on this basis the combination arrangement, using the reciprocating engines and with the turbines revolving idly, would give about 30 per cent. greater economy than the all-turbine arrangement at cruising speeds.

At cruising speeds, 12 to 14 knots, one-fourth to one-third power will be required. This will be equal to three-fifths to three-fourths of the power of the reciprocating engines proposed. It also is the point at which these engines work at their greatest economy. At this point the reciprocating engine will be about 5 to 10 per cent. more economical than when operating at one-third to one-fourth power, the condition met with the twin-screw reciprocating engine at cruising

speed. Therefore the proposed combination would give an advantage of 5 to 10 per cent. in economy, at cruising speeds, over the all-reciprocating engine using two engines.

Summing up, then, the following will be accomplished by the combination when using the turbine entirely independent of the reciprocating engines:

1. An increase of about 30 per cent. in economy over the all-turbine arrangement at cruising speeds.

2. An increase of 5 to 10 per cent. in economy over the twin-screw reciprocating-engine design at cruising speed.

3. An increase of about 6 per cent. in economy over the twin-screw reciprocating-engine design at full speed.

4. A decrease of about 4 per cent. in economy over the all-turbine arrangement at full speed.

5. About the same space and weight will be needed as for the twin-screw reciprocating design or for the all-turbine three or four-screw design. Everything, however, points to a considerable saving in both weight and space by the adoption of the combination.

6. Less space and weight will be needed than for the three-screw reciprocating design.

7. Increased reliability over the all-turbine arrangement would be secured. Four-tenths power for either ahead or backing is given by a thoroughly reliable and familiar machine.

8. As great, and probably greater, reliability is obtained than with the twin-screw reciprocating-engine design.

9. Greater efficiency for the propellers can be obtained for both full speed and cruising speed. The turbine propeller can be designed without special regard to very low speeds, and the reciprocating-engine propellers can be designed to give their best effect at near cruising speeds. When going at high speeds the propellers of the reciprocating engine would be working at a slightly decreased efficiency.

10. Full four-tenths backing power can be secured exactly as with the present reciprocating-engine design.

11. Smaller engine compartments can be used, and hence

greater chances of stability should one of the compartments become damaged.

Such a combination may be slightly modified and a still greater economy at cruising speeds obtained. This is accomplished by operating the reciprocating engine and the turbine as a combination in series.

The proposition of a combination of reciprocating engines and turbines has recently been the subject of articles by Hon. C. A. Parsons and R. J. Walker in the "Transactions of British Institution of Naval Architects," 1908. This proposition is there specially confined to merchant vessels of moderate speed, 16 knots and below. The *Laurentie* now building for the White Star Line has this combination feature.

The same reasons that would make such a combination desirable for a merchant vessel will hold for a battleship or other man-of-war where moderate speeds are largely used. A battleship should not be considered a race horse; her province is to fight, not to reconnoiter or to run.

In this installation the boiler steam is admitted into the reciprocating engines and exhausted from them (at from 20 to 7 pounds absolute) to the turbine, which carries on the expansion; finally exhausting into the condenser with a vacuum of 28 inches.

By this combination the power will be about equally divided between the reciprocating engine and the turbine when the initial pressure at turbine is about 15 pounds absolute. By this combination it is claimed, and fairly-well substantiated by reliable data, that a steam consumption of about 12 pounds of water per I.H.P. can be obtained, a result beating by about 20 per cent. the best results of either all-turbine or all-reciprocating marine-engine installation.

This economy is effected owing to the fact that the turbine can use the lower ranges of expansion much more efficiently than can the reciprocating engine, and conversely the reciprocating engine can, and does, use the higher ranges at reduced powers more efficiently; so that by the combination each system uses the steam at the point and under the conditions where it can handle it most efficaciously.

In the system proposed for a battleship, it is designed that at full power the turbine and the reciprocating engines shall act independently, each taking steam at boiler pressure and exhausting into its own condenser. But at reduced power (below two-thirds power) the two systems are to work in combination, the reciprocating engine exhausting into the L.P. turbine. In this way the machinery plant will give its maximum economy in steam consumption at the cruising speed. With the all-turbine arrangement the greatest economy is at full speed, and at any considerable reduction the economy drops materially.

By using the reciprocating engine and turbine in series a far greater efficiency in steam can be obtained at reduced speed than by either the turbine or the reciprocating engine separately. The reciprocating engine will utilize the higher ranges of pressure and the turbine will use the lower range. In either case the engine will use the steam in a most efficient manner, and in a more efficient manner than if either type of engine used the whole range.

In this combination it is proposed to have for the L.P. cylinder of the reciprocating engine (besides the regular exhaust into its own condenser) an alternate exhaust leading to the L.P. turbine and also to the turbine condenser by another pipe. This would be arranged so that when operating in series with the turbine and going ahead the exhaust steam from reciprocating engine would pass through this exhaust and lead by means of a pipe to a valve at L.P. turbine. If the reciprocating engine is backed a connection from the reversing gear would operate a differential valve which would shut off exhaust from the L.P. turbine and throw it open to the turbine condenser. The operation of reversing when thus running in series would present no difficulty whatever, and while running combined the turbine condenser would handle all the exhaust steam and the condenser of the reciprocating engine could be shut down.

At very low power it might prove to be more economical to shut steam off the turbine altogether and run with the re-

ciprocating engines alone. This would be a matter to be determined by actual practice.

In this installation it is contemplated that the turbine be in two parts, a high pressure and a low pressure, and the exhaust from the reciprocating engine would be led to the throttle on steam chest of the L.P. turbine.

When running in series the H.P. turbine would simply revolve either in vacuum by drain connections to condenser or at atmospheric pressure.

The exhaust being led to L.P. turbine will cause this turbine to be operated at somewhere near its most efficient speed when the pressure of steam at this point is approximately at that of the atmosphere.

Using the reciprocating engines in combination with the turbine at from one-fourth to three-fifths power an economy of water consumption of about 12 to 13 pounds of water per I.H.P. can be obtained.

With triple-expansion engines this result at the above power would be about 16 pounds of water.

With turbines the above result will be about 18 to 20 pounds of water.

The combination, therefore, for cruising speeds has the advantage of 15 to 25 per cent. in economy over the all-reciprocating engine arrangement, and the advantage of 25 to 35 per cent. over the all-turbine installation.

As this installation has not yet been made definite or exact, results cannot be stated, but from what we now know of the operation of the reciprocating engine and of the turbine at reduced speeds, and the surprising economy of such combinations on some land engines, sufficient data is at hand to show that the combination can be made to secure a decidedly better all-around service economy than either the all-reciprocating or the all-turbine arrangement produces.

By the installation of the combination not a single advantage of the reciprocating engine is lost. The disadvantages of the turbine are overcome and its advantages are retained.

Both weight and space are saved to a slight extent.

Smaller engine-room compartments can be used, thereby improving the watertight subdivision and increasing stability.

The running economy is enormously increased.

Full maneuvering ability is secured.

The only possible point of disadvantage is a slight reduction in economy at full speed.

The point of complication may, perhaps, be raised against the proposed arrangement, but in point of fact it is much simpler than an all-turbine design when, besides the main turbines, there are separate cruising turbines and backing turbines. These extra turbines, with their piping, cause a very considerable and objectionable complication.

In the proposed plan as shown in sketch, another simplification is proposed in that there would be no auxiliary condenser installed, the condensers for the reciprocating engines being arranged to take care of the auxiliary exhaust drains, etc., both in port and when underway.

With this combination an accident to the turbine would not disable the ship or her ability to maneuver. The turbine could be repaired at leisure and the vessel still kept in condition for steaming at nearly half power during the time repairs were being made.

CONCLUSIONS.

In summing up the advantages and disadvantages, the arrangement suggested, either using the engines separately or in series, seems to present a much greater all-around efficiency and economy than either the all-turbine or the all-reciprocating engine arrangement does. It is suggested as something well worth investigating and trying for use in moderate-speed men-of-war, colliers or transports. The all-turbine arrangement will be quite unsatisfactory in economy at cruising speeds and for maneuvering purposes, so if we wish to try and realize some of the great benefits that turbines have, this appears to be a way in which they may be realized to a large extent without sacrificing the economy and reliability at cruising speeds, which the reciprocating engine undoubtedly has.

SUBMARINE NAVAL WARFARE.*

By G. Laurenti, Major Constructor, Royal Italian Navy.

Until recently the principal means for coast defense consisted of artillery and of submarine mines. The development of submarine mines indicated that artillery was not considered sufficient in itself to resist the assaults of an energetic enemy, but that it should be supplemented by the provision of obstacles and concealed dangers. At the present time, however, fixed mines are considered of minor importance, principally because of the deterioration of the electric cables connecting them to the shore. Apart from the rulings of the Hague Conference, the use of mechanical contact mines may be considered as a partial means of offense, since they act to blockade a squadron within a harbor, or may be employed to make a bay impracticable. They are, however, undesirable as weapons of defense for a military port, since they are dangerous to any vessel crossing their lines, and their recovery is difficult after the termination of hostilities; besides which they are liable to be displaced by currents, and thus become dangerous to neutrals. Floating torpedoes are found unreliable in service, owing to the rapid deterioration of their delicate mechanism, and hence recent efforts have been directed toward the perfection of the submarine boat. Such boats, controllable beneath the surface of the water, according to the movements of the enemy, and carrying on board a number of torpedoes ready for service, now constitute the most effective means for operating successfully against an opponent. The submarine boat may be considered as the arm of ambush *par excellence,* and although

* Reprinted from "Cassier's Magazine," Nov., 1908.

in France and England Fulton's early plans for submarine warfare were condemned as savoring of piracy, yet at the present time such methods are considered as entirely legitimate, as leading to success in naval warfare.

The torpedo boat was designed originally as a vessel for attack by surprise, but an experience of nearly twenty-five years has shown that this method is of very limited value. It is folly for a torpedo boat to attack a prepared enemy in broad daylight, while at night it is most difficult to determine the distance and direction of vessels in motion. Recent British trials have demonstrated the difficulty of hitting a target with torpedoes launched from a torpedo boat at night, while submarine boats, attacking vessels in motion and aware of the attack, succeeded in making 80 per cent. of hits.

Boats intended for warfare beneath the surface are divided into two classes, namely, "submarines" and "submersibles," but the precise characteristics of these two classes are not very clearly defined.

In general, the term submarine is applied to a boat having but a small radius of action, while a submersible is one of greater capacity. A more correct basis of difference, however, would seem to be that of the reserve of buoyancy, according to which all boats having but a small reserve, say from 10 to 15 per cent., or less, might be termed submarines, while those with a larger reserve of buoyancy would come under the classification of submersibles. A small reserve of buoyancy renders a boat little adapted for long voyages at the surface, and hence it is unnecessary to arrange such vessels for a large radius of action, whilst those included under the classification of submersibles, having a larger portion unsubmerged, may be better equipped for a larger radius. Probably a more rational classification is that which describes all submarine torpedo boats as adapted either for coast defense or for high-sea service, corresponding somewhat to the practice obtaining with ordinary torpedo boats.

Taking into account first the form of the hull, the conditions

involved in ordinary floating operation include simply such lines as give the least resistance at the maximum required velocity, and also furnish the best nautical qualities. For a real submarine, that is, a vessel having but a short radius of action at the surface, and intended principally for operation under water, the form adapted for minimum resistance beneath the surface should be given entire attention, while for submersibles, designed for long voyages either upon or below the surface, both conditions should be carefully studied.

FRENCH SUBMARINE "GRONDIN," SHOWING DEPRESSION OF STERN WHEN UNDER WAY.

In addition to the resistance to motion, however, there must also be considered the crushing action of the external pressure. Theoretically the cigar form of hull is assumed to offer the following advantages:

1. Least resistance to motion under water.
2. Maximum resistance to crushing in proportion to weight.

The first advantage is very materially affected by the presence of superstructures necessarily attached to the hull, these also affecting the weight and requiring heavier plates than indicated by theoretical computations. In practice, therefore,

the defects of the cigar-shaped hull may be enumerated as follows:

1. Large resistance for surface navigation.

2. Tendency to depress the stern, both for surface and submarine navigation.

3. Lack of longitudinal stability in surface navigation.

4. Lack of space for the machinery, especially near the ends.

The first defect is due to the waves formed by this particular shape of hull, and for this reason a speed is soon reached at which the resistance when traveling on the surface is greater than that when moving beneath the water. The second point is really a question of dynamics, due to the fact that the water has a tendency to mount the stern and cause its depression, as is shown in the illustration of the French submarine *Grondin*. This action is modified either by the addition of superstructures, as in the British submarines, classes "B" and "C," or those of Lake and Equivilley, or by the provision of an initial depression of the bow by means of water ballast, as in the case of the American submarine *Shark*.

This tendency to depress the stern constitutes one of the principal defects of a submarine, and was first observed in the early trials of American submarines, in which it was noticed that the horizontal rudders had to be operated in order to raise the stern. This question was also made the subject of experimental investigation by Naval Constructor D. W. Taylor, in the Government testing tank at Washington.*

The results of these experiments fully confirmed the observations at sea. In consequence Mr. Taylor examined the behavior of a series of submarine types with vertical bow and stern and found these to give a better longitudinal equilibrium when propelled under water.

The insufficient longitudinal stability at the surface is due to the comparatively short length of immersed surface, as was well shown by Sir William White in his investigation of the loss of the submarine *"A 8."*†

*See "The Limitation of the Diving Submarine," by R. G. Skerrett, "Journal of the Royal Artillery," June, 1907.

† Report before the Royal Society, May, 1906.

This defect may be eliminated by the use of a braced superstructure, acting to lengthen the hull, but this involves an increase in weight without the addition of a corresponding transverse strength.

By reason of these defects in the cigar-shaped hull various other forms have been devised, taking into account the requirements both of surface and submarine navigation. Among these, one of the first was that used by the French engineer, Laubeuf, who, in the *Narval* (1896) adopted a mixed construction, consisting of a double hull; the outer skin being of light plates of a form adapted for surface navigation, and an inner shell with transverse bulkheads to resist the external crushing pressure. This design has advantages, so far as the external form is concerned, and gives additional strength to resist collision, but it has the defect that the space between the two hulls cannot be pumped out at great depths, because the outer shell is too light to resist the pressure.

ARRANGEMENT OF SUPERSTRUCTURES ON BRITISH SUBMARINE "B4."

Since external superstructures are considered indispensable in connection with surface navigation, it has been found possible to utilize them to aid in giving transverse strength, and to use other forms of cross-section than the circular for the hull. In the submarines designed by the author the inner and outer hulls are both used to resist the external pressure, and

the superstructure is designed so as to stiffen the upper part of the boat.

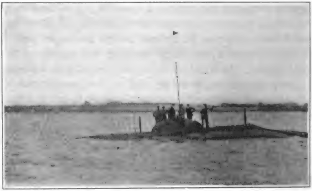
The reserve of buoyancy differs very much in boats of different designs, ranging from a minimum of 5 per cent. of the total displacement in some of the French types, about 10 per cent. in the English and American Holland boats, to 20 per cent. in the Lake boat, and 30 per cent. in the French diving boats of the Laubeuf types. The nautical qualities of the boat depend very much upon the reserve of buoyancy, and in general, the larger this reserve the better the qualities. For coast-defense submarines, intended to protect bays, harbors and channels, the reserve buoyancy may be allowed as low as 10 per cent., but for boats intended for longer cruising the reserve must be much greater. In some of the recent submarines the reserve buoyancy reaches nearly 60 per cent. of the displacement, thus approximating closely the ordinary torpedo boat, and having nearly as good nautical qualities. In the case of an ordinary vessel the two elements of stability are the reserve buoyancy and the metacentric height. For a submarine, however, it is possible to have a metacentric height suitable for surface navigation, while at the same time the reserve buoyancy may be reduced either to zero or to a minimum of not more than half a ton in either small or large boats. This means that even a small influx of water in a submarine, while beneath the surface, might prove disastrous if not immediately followed by a corresponding lightening.

It would be possible to maintain a greater reserve of buoyancy while navigating beneath the surface if a portion of the motive power were diverted to maintaining the submergence, but this would be at a sacrifice of propelling power, and hence of speed.

Since submarines must be operated under two different conditions, namely, at the surface and beneath the water, it is necessary to have two independent sets of motive-power machinery. As the permissible weight for the machinery has to be divided between the two portions, the power of each is lim-

ited, and this fact alone prevents a submarine from competing in speed with a surface vessel. A high speed, however, is not required for a submarine boat, as it is in the case of scouts or torpedo boats, in which speed is the only arm of defense.

There is at the present time no type of submarine boat combining maximum speed both on the surface of the water and when submerged, and the opinions of engineers are divided as to the relative importance of the two portions of the service.



AMERICAN SUBMARINE "SHARK," SHOWING TRIM WHEN STANDING.

As examples of recent practice we may note the Italian submersible *Glauco,* of 160 tons displacement, designed by the author, which has a speed of 14 knots at the surface and 7 knots when submerged. The latest type of American Holland boat, with a displacement of 245 tons, has a surface speed of 11.5 knots, and 10 knots when under water. There are certain limitations for subaqueous velocity which do not obtain in navigation at the surface of the water. Among these may be mentioned the effect of sudden changes of direction in the horizontal plane, also the effect of speed upon the visibility of the periscope. The photograph of the trail of a periscope shows the extent to which it is visible at a speed of 8 knots, and under such conditions it is impossible to assume that the position

of the submarne could remain unobserved. The periscope is indispensable to conduct an attack with any probability of success, and since the submarine, even at a speed of 10 knots, must necessarily be much lower than the maximum speed of a battleship, it is generally thought better by designers to make the speed below the surface secondary to the safety of the men and the secrecy and success of maneuvers.

The propelling machinery of a submarine for surface navigation is generally thermal, while the propulsion beneath the water is effected by electric power. So far there has not been developed any satisfactory type of propelling machinery adapted for both functions, although various plans have been devised with this end in view.

The surface propulsion has been effected both by steam engines and by internal-combustion motors. In addition to the submarine boats built by Nordenfelt nearly twenty-five years ago, steam power has been employed on some of the French submarines, but these plans have not been reproduced in the latest designs. In the steam-propelled submarines very light water-tube boilers were used, with kerosene as fuel, the steam being used in ordinary reciprocating engines; the steam turbine has not been applied as yet to any submarine. The advantages of steam power lie principally in the flexibility of the engine, and in the ease of reversing, but in a submarine steam is inconvenient on account of weight, space occupied, heat developed and noxious gases produced.

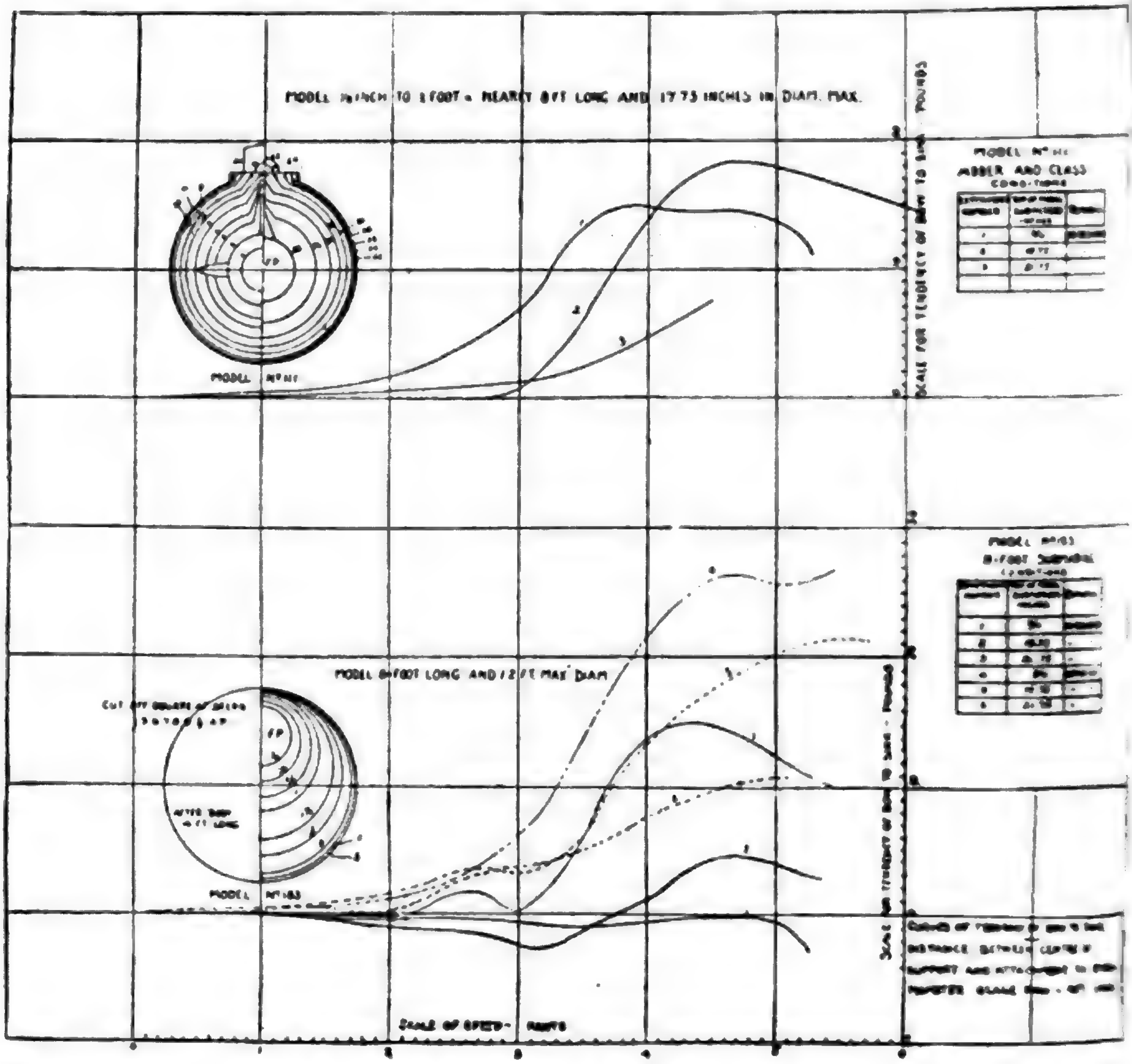
The latest tendency is to use the internal-combustion motor, and although many practical difficulties have been encountered in its application, these have nearly all been overcome during ten years' experience and effort. Combustion motors, as applied to submarines, may be classed under three heads:

1. Motors using a mixture of air and vapor of gasoline or benzine.

2. Motors using a mixture of air and vapor of lighting kerosene.

3. Motors burning heavy oils.

Until recently the motors of the first variety have been most extensively used. Those who have had no practical experience with gasoline motors in submarine boats have thought such machines objectionable because of the liability of formation of an explosive mixture with the air of the room, but a



EXPERIMENTAL RESULTS WITH MODELS OF SUBMARINES IN THE TESTING TANK AT WASHINGTON.

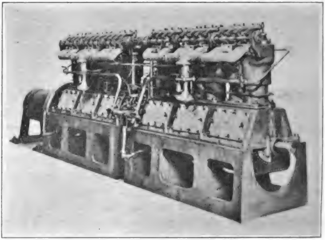
comparison of the dangers of such motors with those using kerosene will show that the first class is to be preferred to the second. The gasoline motor is more easily started, more easily installed, and is lighter and less objectionable than the kerosene engine. Any danger which might exist from the

production of explosive vapors may be avoided by a proper ventilation of the engine room, and experience in a number of British submarines, involving motors up to nearly 900 horsepower, has shown no trouble from this source. The latest types using high pressures, forced lubrication and liberal water-jacketing for cylinders and exhaust pipes have proved very reliable and satisfactory.

FRENCH SUBMERSIBLE "NARVAL."

Motors using illuminating kerosene in submarine boats may be divided into two varieties, those using a flame vaporizer and those vaporizing the fuel by the heat of the exhaust. An example of the first type is the Gardner motor, used, it is said, in one of the French submarines. The flame vaporizer has the advantage of elasticity, since the operator can regulate the vaporization of the fuel independently of the operation of the engine, but the "bruleurs" are rather delicate pieces of apparatus, and the presence of open flames in a small closed engine room is very undesirable. In the second class may be noted the Koerting and the Thornycroft motors, the former being used in the submarine boats built for Germany and Russia at the Krupp yards at Kiel, while the latter has been used in two submarines built by Thornycroft for the Italian Government. The Koerting motor is of the two-cycle type, and in starting the fuel is vaporized by an electric current, and after the engine is started the heat of the exhaust gases is employed. The Thornycroft motor is a four-cycle engine and is started by benzine, the kerosene being used after the engine is well under way, and the heat of the exhaust is available. The objection to this type of motor lies in the fact

that the speed cannot be reduced below a certain number of revolutions without reducing the temperature of the exhaust to a point where the vaporization of the fuel is not properly effected. Such engines also require water injection in the cylinder in order to permit the use of a high compression without premature ignition, and unless distilled water is used the durability of the motor is apt to be affected. Such engines require more attention than the gasoline motors and the consumption of fuel is somewhat higher.



FIAT GASOLINE MOTOR OF 300 BRAKE HORSEPOWER AS ARRANGED FOR SUBMARINE.

Better results are obtained by the use of the Diesel motor, burning heavy oils, especially in connection with the two-cycle Diesel motor built by Sulzer Brothers. The first submarine in which the Diesel motor was used was the French boat "*Y*," and some difficulties were encountered because of the conditions under which the engine had to work. In the later French submarines of the *Topaze* type and the submersibles of the *Pluviose* type, the Diesel motor of the four-cycle design has been employed with success. The two-cycle type of Diesel

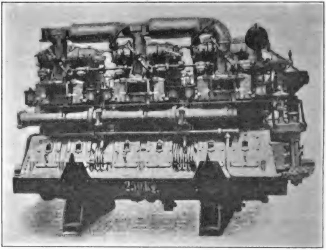
motor, however, is the latest design, and in some of the recent Diesel engines built by the Nuremberg Maschinen Fabrik, the weight has been reduced to 12 to 15 kilogrammes per effective horsepower, or about the same as a benzine four-cycle motor running at the same speed. The great advantage of the Diesel motor lies in the fact that it is able to burn all kinds of heavy oils up to a density of 0.9, thus giving the greatest security against fires and explosions, while, at the same time, it is ready to start at any time, and requires no preliminary heating of the fuel.

In designing a heat motor for use with a submarine, its relations to the electric machinery used for navigation below the surface must be considered.

The modern tendency is to arrange the two motors on the same shaft, without the interposition of any gearing or other intermediate mechanism. In order to permit the two motors to be operated, each to the best advantage, the plan of using a propeller with adjustable blades, controlled from the interior of the boat, is employed in the later submarines, the Meissner propeller being an example. Screws of this sort have not, as yet, been used above 300 horsepower, but there appears to be no reason why this should not be exceeded. In the case of some small submarines, of which the French type *Naiade* of 68 tons is an example, electric power has been used, both for the surface and submarine propulsion.

All the submarine boats now in service use electric power for propulsion beneath the surface. Some of the earlier boats, such as the *Plongeur,* of Bourgois and Brun, made in France in 1863, used compressed air both above and beneath the surface, while the Nordenfelt experiments in Sweden and in England in 1884-1885 used a steam engine for both purposes. Recently some attempts have been made to use the internal-combustion engine for motive power when submerged. In France, in 1904, the submarine *"Y"* was launched, according to the designs of Bertin, and equipped with a Diesel motor, supplied with compressed air from tanks when operating beneath the surface. Tests with this apparatus, however, did not warrant

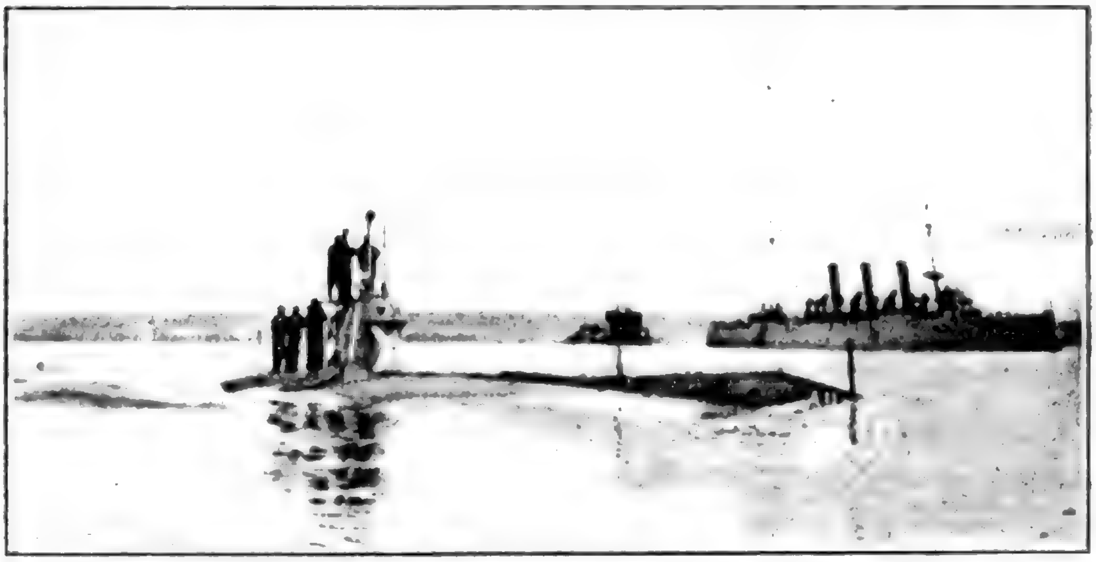
a continuance of the system, and this boat has since been equipped with electric power for submarine service. More successful experiments have been made in Russia with the Drezwiecki system. In this case a small boat, provided with a benzine motor, was operated for more than an hour beneath the surface, and no serious inconvenience from heat or foul air was reported, but the noise was found objectionable. The visibility of the exhaust discharged below the surface of the water is a defect of this system, but this is not of serious importance if the water is even slightly rough. The French engineer Sabathe has proposed to operate the Diesel motor upon a closed cycle, the engine drawing in its own exhaust gases, together with sufficient oxygen to burn the fuel charge, so that the volume of exhaust gases is greatly reduced, and the perfection of combustion would result in the production mainly of carbon anhydride, almost wholly soluble in water, and thus give an invisible exhaust.



KOERTING PARAFFINE MOTOR FOR SUBMARINES,
125 BRAKE HORSEPOWER.

The Italian engineer Del Proposto has devised another type

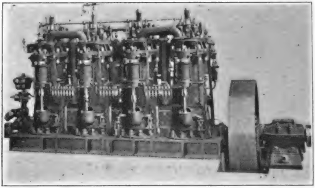
of propelling mechanism, which, it is understood, is to be installed in a large submarine soon to be built for the Russian Government. The system involves the use of two Diesel four-cycle motors with four cylinders each. During navigation on the surface one of these motors is used to compress large volumes of air to a high pressure in suitable storage tanks. During operation beneath the surface, one of the cylinders of the Diesel motor will be operated by compressed air, the exhaust from this cylinder being discharged into the engine room for the purification of its atmosphere, and also being drawn from thence into the other cylinders during the suction strokes, these cylinders operating as a combustion motor. It is practicable to proportion the parts so that an equilibrium of action may be



THE BRITISH SUBMARINE "A11," WITH NEW TYPE OF CONNING TOWER.

obtained on this principle, and at the same time obtain a greater power when navigating below the surface than when above, the two speeds thus being almost equal. When very near the surface, as when about to discharge a torpedo, any visible exhaust may be avoided by operating all the cylinders of the Diesel motor with compressed air, the exhaust being delivered into the engine room. Since it is possible for men to support a pressure of nearly four atmospheres without serious inconvenience, it would thus be practicable to operate a submarine for several miles at high speed without revealing its presence.

It is understood that it is only by the use of some form of combustion motor beneath the surface that high submarine speeds can be attained; Del Proposto expects to reach a speed of 15 miles per hour.



DIESEL FOUR-CYCLE MOTOR OF 140 BRAKE HORSEPOWER, ARRANGED FOR SUBMARINES.

The principal difficulty with electric power in submarines appears in the weight of the storage batteries and the space required for them. The lightest batteries now used by submarines weigh not less than 40 kilogrammes per horsepower when operated at high rates of discharge. A lighter weight per horsepower may be obtained with slower discharge, but the total power available will be reduced. The capacity is always limited, and it is hardly practicable to operate a submarine more than three or four hours under water at full speed. Nevertheless electric power offers many advantages for submarine use, among which may be noted the following:

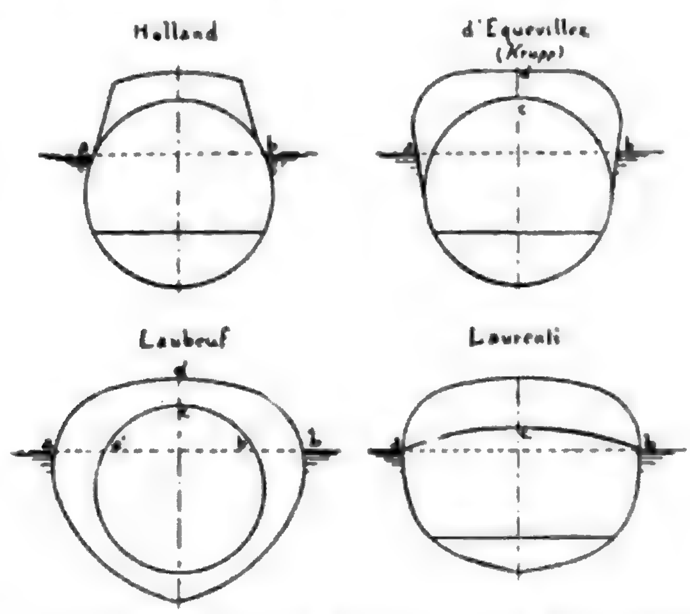
1. Uniform weight during the entire period of operation; a feature of much importance in submarine navigation.

2. Quietness during operation.

3. No heat developed, and no deterioration of the atmosphere when the apparatus is properly managed.

4. Ease of subdivision of power for the operation of motors for pumps, fans, etc.

The electric motors used in submarines are of the multipolar type, with either compound or derived windings. Except in some special instances, the motors operate at uniform speed with constant current, the variability of speed, about 15 per cent., being obtained by means of a resistance interposed in the field. For greater speed variations it is usual to vary the voltage by subdivision of the batteries; operating the sections either in series or in parallel as may be required. The minimum voltages used for operation in parallel are from 100 to 200 volts, and for series operation from 200 to 240 volts. Above 200 volts, however, it is difficult to maintain satisfactory insulation, and hence in the latest designs it is planned to maintain the voltage uniform, as 100 to 200 volts, and use motors with compensation poles, thus permitting speed variations from 1 to 1/5. This involves a somewhat greater weight for the motors, but the advantages are sufficient to permit this.



Characteristic Cross-Sections of Submarines.

When two forms of motive power are employed, the heat motor is used to charge the batteries, and boats thus equipped are termed "autonomous" because they do not require special charging stations. The accumulators employed are generally of the ordinary sulphuric-acid type, with Faure negative plates, and either Planté or Faure positives. Batteries of the Edison type, with alkaline electrolyte, and plates of nickel salts

appeared to offer many advantages, but they have not proved satisfactory. The accumulators form an important portion of a submarine, and constitute a large part of the weight of the machinery, and when cared for with intelligence and judgment they give very satisfactory results. In the French submarines the batteries are generally of the "Fulmen" type, using d'Arsonval positive plates; the English boats use the "Chloride" type; the German and Russian are equipped with the batteries made by the Hagen Accumulatoren Fabrik; while the Italian submarines use the accumulators made by the *Societa Generale Italiana Accumulatori Eletrici,* which is a branch of the Hagen works.

In general the batteries are made with ebonite cells, some hermetically sealed, others not sealed, the acid being carried at such a level as not to be spilled by the rolling of the boat. In order to avoid inconvenience from the motion of the electrolyte in the cells, a special form of Hagen battery has been made under the Krupp patent with an absorbent material between the plates to take up the excess of liquid. In order to secure a reduction of weight, some recent batteries have been made with both the positive and negative plates on the Faure system, and this will prove satisfactory if the positive Faure plates prove as durable as those on the Planté system.

The principal difference between the batteries in the various types of submarines appears in the sizes of the elements, the shape of the cells, and the method of removing the gases which are evolved. In the British and American submarines of the Holland type, as well as in the Lake boats, and in some of the Russian boats, elements of large size and weight exceeding one ton have been used, while in the French boats the weight is about 200 kilogrammes, and in the Italian submarines about 100 kilogrammes. The object of using large elements is to obtain the greatest capacity with the least weight, but there are a number of objections to such a practice. Thus, large elements are difficult to instal, and have often to be made in several parts to permit them to be passed through the hatches; besides which it is difficult to replace damaged parts. With

large elements, also, any damage puts a considerable portion of the entire battery out of service, while the contrary is the case with smaller elements.

An important matter is the removal of the gases which are evolved from the battery, especially during the latter part of the period of discharge. As is well known, these gases consist of oxygen and hydrogen in such proportions as constitute an explosive mixture, besides being non-respirable, and a number of serious accidents have occurred by their accumulation.

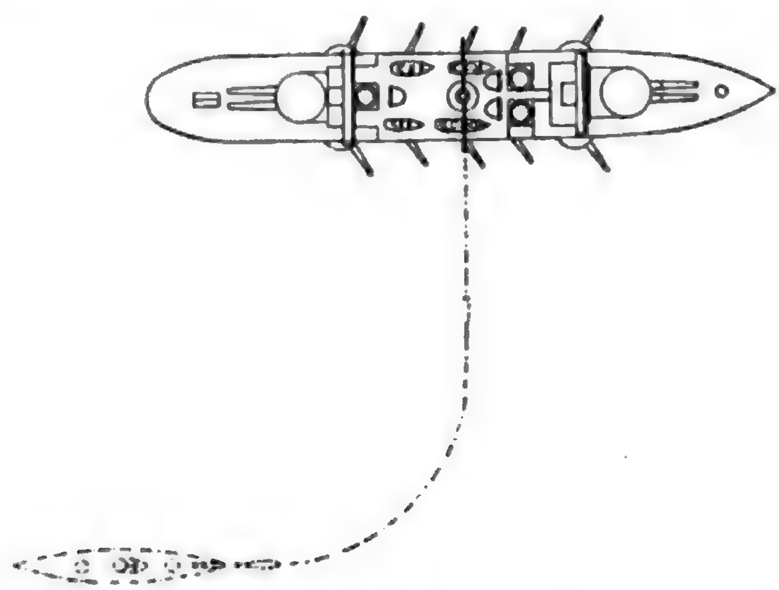


DIAGRAM ILLUSTRATING PATH TAKEN BY A TORPEDO, AUBRY SYSTEM.

Owing to the acid vapors carried off with the gases their escape produces injurious corrosion of the machinery, and hence their removal is a matter of importance. Several methods have been employed for dealing with this difficulty. If the cells are not hermetically sealed, a method followed in the French boats, and in those built by Krupp, the gases escape into the boat and are drawn off by the use of electric exhaust fans. This plan is objectionable because the air of the boat is vitiated and because it is not possible to insure the clearing of all parts of the vessel. Another plan, used in the Holland and the Lake submarine boats, consists in enclosing the cells in a large case, from which the gases are drawn off by a ventilating fan. This is an improvement over the first method; but it is not altogether safe, as there is a possibility of the

explosive mixture in the enclosing chamber becoming ignited from a spark from the electrical apparatus. A third plan, introduced by the author in some of the Italian submarines, consists in sealing each cell airtight and providing it with a vent hole and tube, the several tubes all being combined into one collector which is exhausted to the exterior of the boat. During the charging of the battery sufficient air enters through the main collector to change the composition of the mixed gases and produce a non-explosive mixture. This system has been found successful in practice, and in no case has an explosion ever occurred.

Submarine navigation is the principal function of submarines and submersibles, and to it the greatest attention must be directed. Three problems are involved in successful operation: (1) the vertical movement; (2) horizontal navigation at a pre-determined depth, and (3) maintenance of a required stationary position.

The volume of a floating hull may be divided into two parts: the immersed portion, displacing a quantity of water equal in weight to the weight of the entire vessel; and the portion which is above the waterline, which, being watertight, constitutes the reserve buoyancy. If the entire body is to be submerged it is necessary to overcome the reserve buoyancy, and this may be effected in two ways. The reserve buoyancy may consist entirely of a chamber distinct from the interior of the boat, in which case the water may be allowed to enter, simply by putting it into communication with the sea. If a portion of the reserve buoyancy is included as a part of the interior of the boat, it is necessary to increase the weight of the hull by admitting a corresponding amount of water ballast. In the diagram, sections are given of four different types of boats, and in each the reserve buoyancy is indicated by the space *a, b, d, a.*

In the Laubeuf system the submersion is effected by putting the space between the two hulls in communication with the sea, while in the other boats a double bottom is provided, the filling of which causes the vessel to sink. In the Holland and

Russo-Laurenti Cleptoscope.

the Laurenti boats the superstructure is entirely above the hull, so that it fills or empties automatically as the boat sinks or rises; in the other designs the superstructures must be emptied mechanically, or by compressed air. The reserve of buoyancy may be just overcome, so that the hull weighs exactly as much as the volume of water which it displaces, or the reserve may not be entirely overbalanced, but a small amount, generally about half a ton, allowed to remain, so that the boat has a tendency to rise, or there may be an excess of ballast added, and the vessel has a tendency to sink. The horizontal path

Model of Italian Submarine, Laurenti Type.

of the boat is controlled by horizontal rudders, generally arranged in pairs on both sides of the hull and connected to the same shaft. In the earlier boats only one pair of rudders was used at the bow or at the stern, but in modern practice two pairs are employed, one pair at each extreme end. In some cases the stern rudders are held at a fixed angle, and the steering effected only by those at the bow, but in other designs both sets of rudders are connected, so that they are operated together.

The behavior of a boat beneath the water is affected by a number of elements, including the metacentric height, the size and position of the horizontal rudders, the form of the hull, and the positions of the total resultants of the propelling and resisting forces. At the present time it cannot be asserted that any particular form of hull is best adapted for submarine navigation. The investigations of Taylor in the Government testing tank at Washington have not as yet given positive results, and when we consider that after many centuries of surface navigation new forms of hulls are developed, improving on the preceding ones, we may also expect a continual development in the form of submarines.

The real purpose for which a submarine is designed is the delivery of torpedoes against the enemy, and while the greatest care should be given to this feature, it is often overlooked by the designer. At the present time there is a difference of opinion as to whether it is better to have a number of external tubes from which torpedoes may be released at the proper moment, or whether internal tubes are to be preferred, from which the torpedoes may be discharged with an initial impulse in a determinate direction. In the case of the external launching tubes or cages, either rigid or swivelling, such as the Drzewiecki, the torpedo leaves the tube by the action of its own propeller, and for this reason its initial velocity is very low, and hence it is not well controlled by its rudder, so that the number of hits with this system is small. It is also found that torpedoes carried in cages outside of the hull of the submarine

are apt to become injured and are often found in bad condition. In the case of the internal torpedo tube the torpedo itself is protected, and being given a powerful initial impulse by compressed air, it starts off in the intended direction, even if its own propeller has not yet begun to act. Experience has shown that it is much easier to hit a mark with the internal tube than by the use of the external cage. The objection has been urged against the internal tube, that it is impracticable to carry as large a number of torpedoes on board of a submarine as in the external cages, and that it is not practicable to discharge a torpedo at right angles to the hull, because of the insufficient width of the boat to carry cross-tubes. From a military viewpoint, however, it is better to have a few torpedoes accurately discharged than to carry a number in unreliable cages. So far as attack at right angles is concerned, this can be effected by the use of the Aubry system, in which the torpedo itself turns in its path. In the use of this system, with the Italian submersibles of the author's design, much success has been attained for several years, the torpedoes making an accurate turn of 90 degrees from the direction of discharge, in a curve of about forty meters radius, as shown in the illustration.

Early Type Submarine, "Holland No. 3."

In the small French submarines the rigid cage, fixed in the direction of the keel, is used, while in the larger boats the swivelling cage, on the Drzewiecki system, has been adopted. In all other navies the system of internal torpedo tubes is employed. In order to enable a single tube to discharge several torpedoes, the Electric Boat Company, builders of the Holland submarine boat, have designed a form of revolver, there being a rotary chamber containing several torpedoes which may be successively brought into position and discharged. When there is but a single torpedo tube it is generally placed at the extreme bow. This arrangement is defective, because any slight collision is apt to damage the tube, or possibly cause the torpedo itself to be discharged, if one is in the tube. For this reason the author has placed the tubes in the boats of his design at some distance from the prow.

The first submarines were blind, and it was not until 1902 that satisfactory appliances were perfected for vision when submerged.

The earlier navigation was conducted by rising to the surface at frequent intervals to make observations as to direction. Now, however, there are a number of satisfactory visual appliances, among which may be mentioned the Ipoidroscope of Howard Grubb, the Telops of Triluzzi, and the Russo-Laurenti Cleptoscope. Each of these devices has its own special features. The Cleptoscope has the advantage that it may use an ocular of 20 centimeters in diameter, and with such a large lens it is possible to cover a field of nearly 50 degrees, objects being seen of natural size, using both eyes without fatiguing the vision and permitting the navigation to be conducted as effectively as with any other type of vessel. Attempts at direct vision through the water have been abandoned, since it has been found impossible, even with optical instruments, to see further than 10 to 12 meters in clear water. This is probably due to defects in human vision, which seems to be different from that of aquatic animals.

Although the commander of a submarine sees what is above his vessel he cannot see beneath it, and hence it is important

that he should be familiar with the nature of the bottom. It is impossible, however, for him to perceive the movements of another submarine in his vicinity, and hence it would be imprudent to send several submarines into the same waters without limiting closely the zone of movement of each boat. The success of recent experiments in the transmission of sound under water has led it to be considered as a method of signalling between two submarines.

The smallest diameter of a good periscope, or rather that portion of it which projects above the surface of the water, is about 10 centimeters, and this is hardly perceptible from a neighboring vessel, and its motion cannot be seen until the speed of the boat reaches about 6 knots, above which speed, as we have seen, the ripples might indicate the position of the submarine.

BRITISH SUBMARINE "A-VI," NAVIGATING AT THE SURFACE.

It is generally assumed that the air contained in a submarine is capable of sustaining life for but a very short time, and many inventors have endeavored to devise systems for the regeneration of the air. Such systems have not proved successful in practice.

It is understood that the amount of carbon anhydride in breathable air should not exceed 1.5 per thousand, while the

normal proportion is 0.4 per thousand. This means that for each person there is required nearly 20 cubic meters of fresh air per hour. This is too great a demand for the capacity of a submarine, but in practice such a quantity is not found to be necessary. It is found that strong and healthy individuals experience little inconvenience in air containing as high as fifteen parts of carbon anhydride per thousand, and that when this limit is reached it may be partially renewed by the admission of a small amount of fresh air from storage compression tanks, with the removal of a corresponding portion of the foul air, this latter being pumped from the lower part of the boat. The possibilities of surviving in contaminated air are shown in the case of the *Farfadet,* where six men lived for 36 hours in a space of only a few cubic meters' volume contaminated by acid vapors from the accumulators.

The mechanical problems involved in submarine navigation for warfare may be considered as solved, and it only remains for the details to be perfected by actual practice in service. It must not be forgotten that in such a complex and highly organized apparatus much depends upon the men by whom it is operated, and that if the best results are expected from such a piece of mechanism it must be placed in the hands of men of the highest ability. Such men have never been lacking in any civilized nation, and unforunate accidents have disclosed true heroes in the service of the submarine. Thus, by the union of the intelligence of the men who have designed the mechanism and the skill of the men by whom it is operated, the world is in the possession of an apparatus to which, in the near future, the coast defense and security of any nation may well be confided.

MELMS-PFENNINGER STEAM TURBINES.

BY INGENIEUR W. MULLER.

Translation from "Die Turbine," by ERNEST N. JANSON, Member.

TRANSLATOR'S NOTES.—The following description of the Melms-Pfenninger steam turbine, although incomplete and for the stationary type, will approximately, it is believed, answer in general features to the turbines which were ordered recently for four out of twelve German torpedo-boat destroyers, and therefore possesses interest as a marine and naval proposition. These four ships are being built by Schichau of Elbing and Danzig, who are also building turbines of same type for a small cruiser. Of the other destroyers four are building at the Germania yards at Kiel, with Parsons; three at the Vulcan yards near Stettin, with Curtis, while one will be fitted with the Zoelly type of turbines.

Practice in new turbine designs, at the present time, seems to favor moderate velocity impulse action in the high-pressure zone with low velocity impulse or combined action and reaction in the low-pressure zones. The turbine in question has foregoing features incorporated.

The mode of balancing the rotor in this turbine undoubtedly possesses merit when used in stationary practice, as the heavy and large-diameter balance pistons are partly dispensed with. The merit of the design appears to exist in the utilization of impulse action in the high-pressure zone, whereby a reduction in the number of vanes rows is rendered possible.

The steam turbine has in later years entered with a firm foothold also in Germany, especially since the inventions and system made and introduced by Parsons were brought into more practical use.

With the names of Parsons, De Laval, Rateau, Zoelly, Schultz, Reidler-Stumpf, Curtis, Westinghouse-Parsons, etc., are identified individual systems of turbine construction, which differ from the reciprocating engine, as well as between themselves, essentially in as follows: In the steam action, reliability of operation, efficiency, space allotment and durability,* any one of which characteristics appear more or less pronounced in the different types.

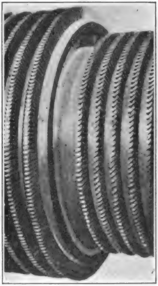


Fig. 1.

The steam turbine has approximately passed through developments similar to those of the water turbine, viz: First, reaction wheels, then impulse wheels, and, last, something between the two. The Melms-Pfenninger "MP" turbines, of which there is already a large number under construction,

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* The author omits mentioning the very great difference in constructional details. Take as an example a Curtis and a Westinghouse turbine of same power, both for a stationary power plant, and, as is well known, there exists no similarity whatsoever in the designs as a whole nor in the construction of parts. The matter of weight enters also as an important consideration in all of the foregoing makes.

form a link between the impulse and the reaction turbines. This is carried out in a way such that in the high-pressure zone pure impulse action is used, while in the middle and low-pressure zones the impulse reaction principle is availed of.

The general arrangement provides for horizontal shaft. The steam inlet to the guide blades in the high-pressure zone is not continuous but is distributed in sections around the circumference, and, therefore, takes place so-called "partial admission."*

The clear circumferential length between the stationary blades of the H.P. zone being very considerably reduced,

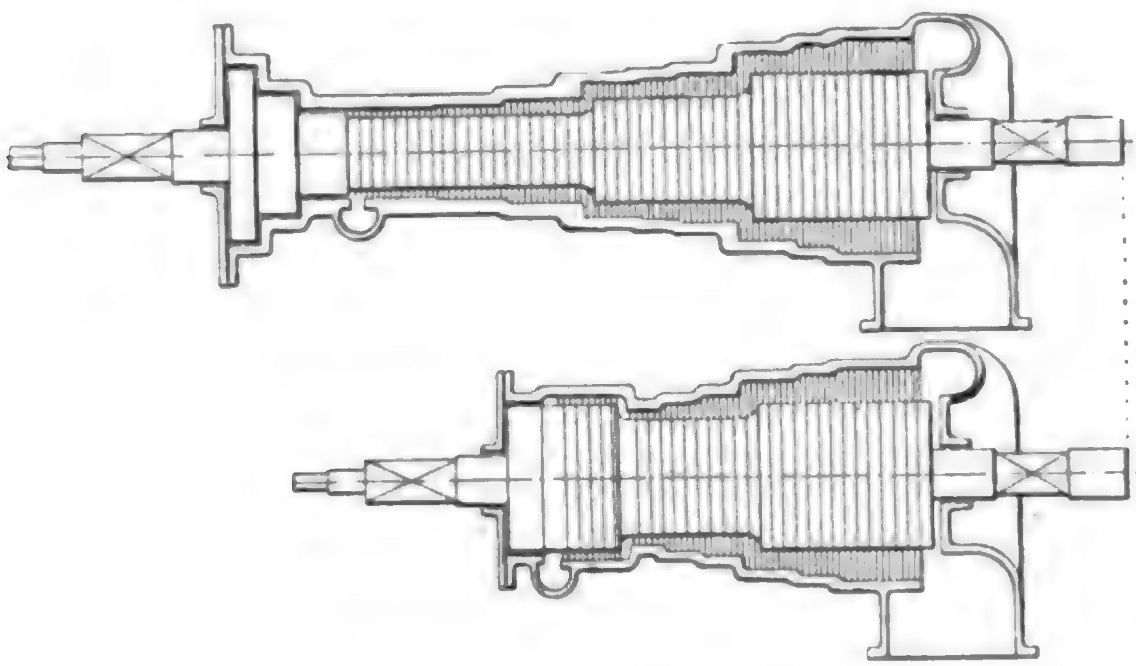


Fig. 2.

admits of longer vanes in this part of the turbine than with circumference unobstructed. The first reaction stage connects at the end of the impulse stage and the drum diameter is here made somewhat smaller. In this way a surface in form of a ring is provided to take up the unbalanced pressure existing in the vane system, which pressure causes a heavy thrust along the rotor.

This arrangement possesses, in comparison with Parsons

* In very early designs of Parsons turbines this seems to have been tried, but abandoned, owing to mechanical and dynamic reasons. This method of admitting the steam to the various pressure stages is one of the principal features of the Rateau turbine.

turbine, great simplicity, obviating its arrangement of balance pistons, and in consequence of the greater heat abstraction by using high velocities, a considerable reduction in the number of vane rows and, therefore, in the length of rotor and casing, as well as over-all diameter, is effected. Some difficulties, such as distortion of the casing caused by differences in temperature in the length direction, are disposed of and dummy clearance leakage is lessened. To illustrate the system, there are shown two views, Figs. 1 and 2. Besides the difference in length, the great difference of diameter (for same power) is apparent. In the combined reaction-impulse turbine (Parsons) it is necessary to use small diameter of drum and short vanes.*

The vanes in "MP" turbines are all on a drum and not, as in most impulse turbines, on discs. In order to diminish the leakage between the stationary vanes and the drum there are provided labyrinth packings. The advantage of a drum construction for impulse turbines is the smaller surface exposed to cause steam friction, which becomes greater with a number of discs.†

Another advantage claimed for this turbine is that superheated steam may be used without detriment, and that thereby its efficiency is considerably raised.

Superheat as high as 120 degrees Fahrenheit at the inlet may be used without danger of distortion. High vacua are, as in other turbines, used to great advantage.

The table appended gives the results of trial undertaken by Prof. Schroter of the Institute of Technology of Munchen with a turbine built for 1,000 H.P. The turbine was con-

* This depends very largely upon circumstances, such as revolutions and horsepower. Thus, with large horsepower and high revolutions, giving satisfactory vane speeds on small drum diameters, the vanes become long, giving small clearance losses. With slow revolutions and small horsepower, they, of course, become very short, with extreme clearance losses.

† The leakage owing to vane clearance must *not* be lost sight of. When on a drum this leakage becomes much larger than when discs are arranged, as then the amount of leakage is determined by the radial clearance in the bushing around the spindle shaft, while, when the drum construction is used, it is caused by an area made up from drum-circumference and radial clearance. Owing to the much higher velocity produced by the higher ratio of expansion prevalent in the individual stages of an impulse turbine, the loss from leakage would be greater than in Parsons turbine with its usually very low steam velocities, unless compensated by the labyrinth packings.

nected to two equal direct-current generators, 2,400 r.p.m. and 230 volts. The electric-driven air and circulating pumps were located in the bedplate. The steam consumption was measured by weighing the condensed steam, and observations were taken hourly under similar conditions of load.

TABLE OF TEST AND PERFORMANCE.*

Trial No.	I.	II.	III.	IV.
1. Load, kw	500.0	400.0	280.0	150.0
2. Mean revolutions per minute	2,459.0	2,469.0	2,477.0	2,489.0
3. Absolute pressure at inlet, pounds per square inch	190.2	188.8	191.7	181.7
4. Steam temperature, in degrees Fahrenheit	607.8	591.0	589.0	552.3
5. Absolute pressure in exhaust nozzle, pounds per square inch	0.5	0.37	0.378	0.52
6. Output at switchboard, kw	498.7	402.9	277.5	146.6
7. Condensation per hour, pounds water	8,570.0	8,570.0	5,140.0	3,297.0
8. Steam consumption 1 kw., pounds per hour	17.7	17.5	18.51	22.49
9. Steam consumption 1 H.P., kw.=1.34 H.P	12.81	13.06	13.8	16.78
10. Comparative steam consumption per kw. hour	100.0	101.8	107.8	130.8

* Converted into English units from the metric system.

THE ELECTRICAL EQUIPMENT OF THE CUNARD EXPRESS STEAMER *MAURETANIA*.*

By Mr. W. C. Martin.

In the equipment of a modern steamship great improvements have been made in recent years for the economical working of the vessel and for the comfort of the passengers. Of all the changes that have been made, none have been more welcome and so thoroughly appreciated as the introduction of electric light.

The first vessel to be fitted was the American steamer *Columbia*, the lighting of which was carried out under the direction of Mr. Edison in 1880. There were 115 lamps of 10 candlepower and two dynamos driven by belts from a counter shaft.

In December, 1881, Professor Andrew Jamieson delivered a lecture to this Institution, in which he stated that electric lighting was fast replacing oil lamps on steamships, and gave a description of the installation fitted on the Cunard steamer *Servia* at a cost of £1,000. When I mention that the total cost of the electrical installation on each of the latest Cunarders has been about £65,000, some idea will be formed of the great progress electrical engineering has made within the last 26 years.

Since the introduction of electricity on board ship, it has proved itself to be the "acme" of perfection for lighting, and has not only added greatly to the comfort of passengers, but has enabled shipowners to utilize lower deck spaces to better advantage for passenger accommodation; and not only passenger vessels have benefited by the adaptability, safety and economy of electricity, but the ordinary cargo steamer of the

* Transactions of the Institution of Naval Engineers and Shipbuilders in Scotland.

present day is taking full advantage of it for the safe and rapid handling of cargo. No first-class cargo steamer is now complete without electric light, and shipowners are finding a great many charters cannot be secured unless their vessels are lighted electrically.

While it would be interesting to follow the development of the various systems of electrical installations on shipboard since the introduction of the first six kilowatt machines on the little steamer *Columbia*, to the 1,650 kilowatts in four machines on the *Mauretania*, I can only make a brief reference to some of the more important points.

In the earlier designs of dynamo construction the generators were run at a very high speed, and in many vessels the power of the engine was transmitted by belts or ropes and counter shafts to the dynamos. Belts on board ship are most objectionable, not only on account of the great space required, but because of their unsteadiness. Many attempts were made in the early days to produce some means of connecting the slow-speed engine and high-speed dynamo without belts, but even the most successful arrangement devised, namely, friction wheels, was found unsuitable for all but the smallest powers. Nothing really reliable for ship work was in use, until the advent of the high-speed steam engine made it possible to couple engine and dynamo directly together. In fact, it was this very demand for a suitable engine that led to the development and perfection of the high-speed engine and steam turbine.

The choice of an engine for electric power on board ship is about equally divided between the slow-speed type at from 200 to 300 revolutions, and the high-speed of from 500 to 700 revolutions per minute, while an occasional engineer prefers a turbine. Engineers in charge of these plants claim to have the most satisfactory results regarding efficiency and economy; but, undoubtedly, the steam turbine is the ideal for ship work. It has all the advantages of light weight, less space, steadier driving, higher efficiency under certain conditions, freedom from vibration, and, having no reciprocating parts, there is less wear. It has been proved that, in smaller

sizes, the turbines are not so economical in steam consumption, but it is almost certain that this will be overcome, and in the near future the turbo-driven dynamo will become universal.

Since the first installations many new fittings and devices have been invented for safe, reliable working on board ship, and the most important of these is the system of wiring, and the protection of the same. The first insulated wires used for ship lighting were covered with cotton cloth and white lead, and a further protection of rubber tubing when passing through specially damp places.

One of the greatest difficulties in ship lighting has been to find wires and fittings that would not be affected by sea air and water, and it still remains a fact that, no matter how good the quality of the insulating material and armored protection may be, if the wires have not been well laid by experienced men, deterioration sets in quickly with most disastrous results. Any electric installation fitted today with the best material and workmanship should last as long as the hull of the ship. Shipbuilders dare not ignore certain standard rules in the building of a ship, but in some instances they are not so particular with regard to the lighting of the same, and it would be to the interest of all concerned if insurance registries and the Board of Trade took a more intelligent interest in this kind of work.

In preparing an installation to be fitted on board ship particular attention should be paid to the placing of the wires, so that they might always be accessible and, above all things, they should be proof against fire and water.

In the Cunard steamer *Servia* there were 117 Swan lamps and 2 arc lamps equal to about 10 kilowatts of 13.4 H.P. In the *Mauretania* the total output of the four electric generators is about 2,200 E.H.P., while the actual power required for all the lights and motors running at one time is 2,773 H.P. It is found in general practice that, the power being very intermittent, two generators are capable of doing the work, thus leaving a large margin in hand for emergencies.

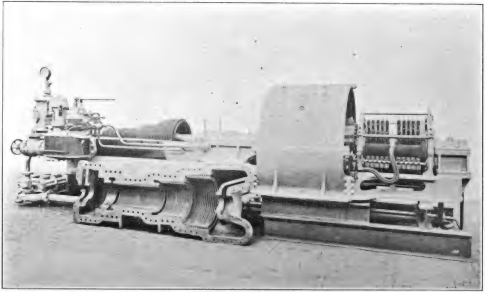


Fig. 1.

To find space for such powerful plant and to fit the installation on the safest and most reliable system, presented some interesting problems. The first of these was to determine the most suitable type of steam generator. After due consideration, the Cunard Company and the builders of the vessel decided to adopt the steam turbine, by the use of which the space required was reduced to a minimum, with less weight and more freedom from noise or vibration as compared with ordinary high-speed engines.

There are four sets of Parsons' turbo continuous-current generators, Fig. 1, each dynamo is shunt wound and is capable of giving an output of 3,750 ampères at 110 volts and 1,200 revolutions per minute. These generators are placed on an elevated platform abaft the engine room, in two separate compartments divided by a watertight bulkhead and arranged so that, in the event of either dynamo room being flooded with water, the ship could still be lighted from the unflooded side.

A better arrangement for the generators would have been to place them nearer the center of the ship, but being a vulnerable part, the Admiralty required them to be placed below the water line, hence the reason for placing them so far aft.

MAIN SWITCHBOARD.

To control this great power with safety and efficiency in a confined space exposed to a high temperature and possible trouble from vibration, required controlling-switch gear of a substantial design, yet sensitive in action. The main switchboard, Fig. 2, is divided into two parts, one section being erected in the port generating room and the other in the starboard generating room.

Each board has two generator panels, twelve feeder panels, and one disconnecting panel. Normally the two switchboards are connected together as one board through the disconnecting switches, but may be separated in a moment from *either* room, and each side of the ship operated as a separate installation.

The use of fuses for the control of the large currents dealt with would have been inconvenient and unsafe, and instead

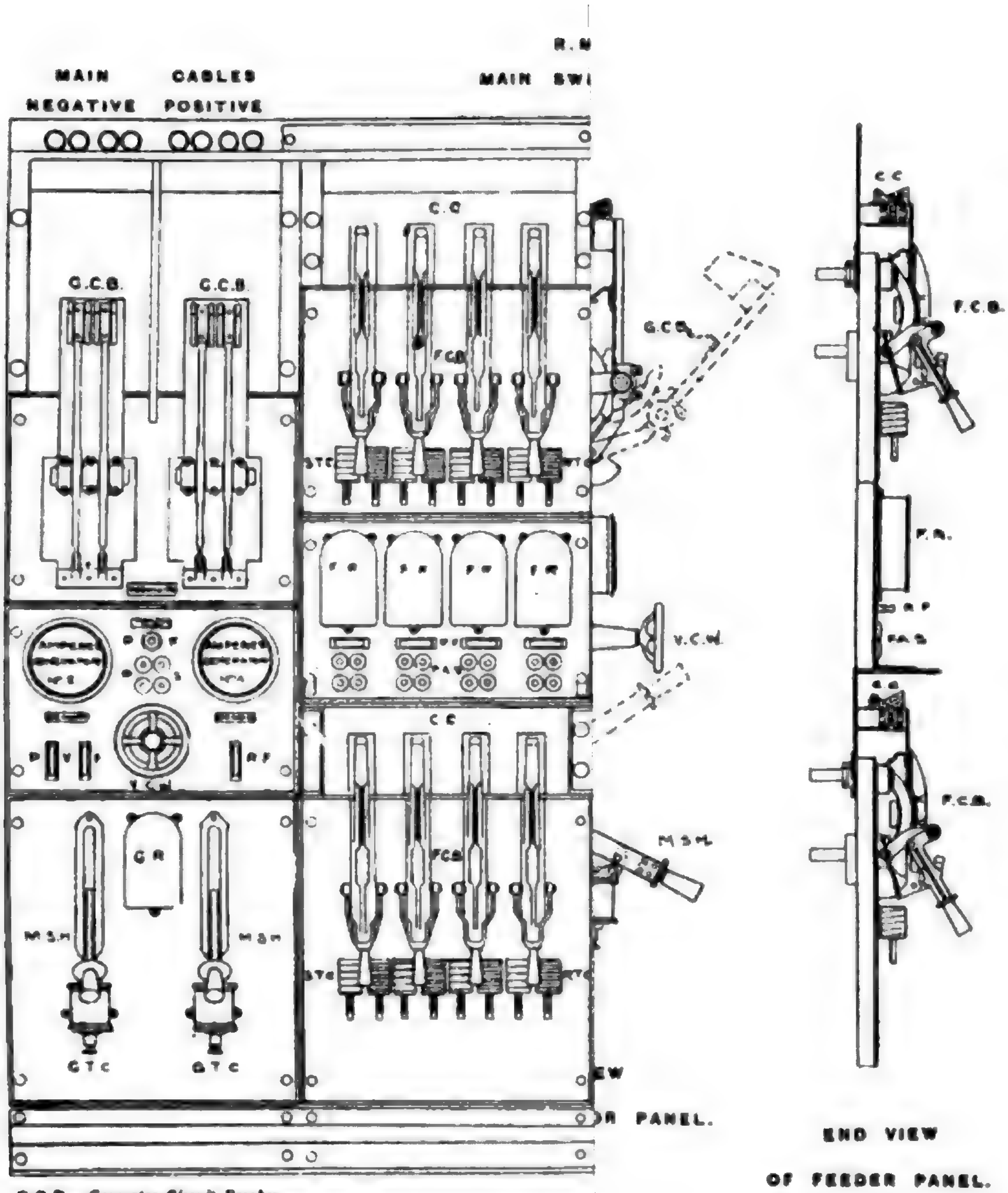
automatic circuit breakers (performing the function of both switch and fuse) were fitted.

These circuit breakers are of massive construction, the contact surfaces being pressed firmly together by levers. The make-and-break contacts are massive carbon blocks, at the extremity of the switch arms, and the main circuit breakers are so arranged that the flash at breaking takes place in fireproof compartments well clear of the attendant. To accomplish this object and to make the operation of the switches easy, the handles are placed below and connected to the switches by insulating links behind the board. These switches are held in the closed position by engaging with a trigger which may be released either by hand or by a trip coil.

In order to prevent the opening of the circuit breakers during a momentary overload, a relay is introduced which closes the trip-coil circuit when an overload occurs, after a period adjustable up to 15 seconds. Should, however, a reversal of current through the generator take place, the relay promptly closes the trip-coil circuit, and thus cuts the machine out of circuit. The opening of the circuit breaker in turn breaks the trip-coil circuit, and prevents damage to the coil or waste of energy.

The feeder switches are operated in a similar way, but without the reverse current arrangement. They have, however, in addition, a trip coil in series with the main current, adjusted to open the circuit with a greater current than the relay is set to operate at, but instantaneous in action. Thus, should a short circuit or heavy overload occur and the relay fail to operate, damage to the cables and machinery is effectively prevented.

The relay is simple and reliable in operation. It consists of a small motor, similar to that used in meters, through which part of the current is shunted. This motor tends to wind a strong silk cord on to a drum against the pull of a weight fastened to the other end of the cord. The cord passes round a drum to which the contact arms are fitted. When the current exceeds the overload limit, the torque of the motor is



G C B Generator Circuit Breaker.
P K Paralleling Key.
P S Paralleling Socket.
V C W Voltage Control Wheel.
P V F Paralleling Voltmeter Fuse.
R F Relay Fuse.
G R Generator Relay.
M S H Main Switch Handles.
G T C Generator Trip Coils.

THE ELECTRICAL RTIN.

sufficient to wind up the cord, and thus close the trip-coil circuits. The adjustments are affected by altering the weights and varying the distance between the contacts.

All the ammeters and voltmeters are of the moving-coil type, the former being operated from shunts in the main circuits. By this means it is possible to have the reading instruments in any convenient place, and in the *Mauretania* two instruments are fitted for each machine, one being in the port and one in the starboard room. On each board one additional ammeter is fitted, connected to bars behind the feeder panels, and so arranged that it may be connected by a plug to any one circuit at a time. By this means the current in any feeder may be ascertained without the expense of separate instruments for each circuit. Two station voltmeters and two paralleling voltmeters are provided, and the shunt regulators, which are placed behind the boards, are operated by a hand wheel on the front.

MAIN CABLES.

The Cunard Company, with their usual precautions for the comfort and safety of their passengers, decided that a high voltage would not be advisable, which accounts for the current being generated at only 110 volts. This necessitated cables of a great carrying capacity, and also very heavy switch gear.

The Admiralty further required all main cables to be run under the water line, and to accomplish this it was necessary to utilize the only available spaces in the coal bunkers or through the boiler rooms. Those who have had experience in the lighting of ships will know that these spaces generally are most objectionable for electric wires, especially the coal bunkers. The high temperature of the boiler room and the very large cables necessitated special precautions being taken to prevent the heat softening the insulation and allowing the cable to sink through the rubber, causing a short circuit. With ordinary armored and lead-sheathed cables, the heat would readily affect the insulating materials. It was, therefore, nec-

essary to adopt fire-resisting covering as well as the usual vulcanized rubber, so that in addition there is a heat-resisting compound and an outer covering of two coats of asbestos braid fitted on the cables. Fig. 3 shows the method of fixing and protection of cables.

The double-wire system is used throughout, and there are 48 main cables of about 2 inches external diameter running from the generating station to the various sections of the ship, Figs. 4 and 5. The power is divided into 24 sub-stations of approximately 100 H.P. each, 12 of these being on the port side of the ship and 12 on the starboard side. Eight of these stations provide power for forced-draft fans, 2 to supply the engine-room machinery and 2 for engine-room lighting, the remaining 12 being connected to auxiliary switchboards at convenient distributing centers throughout the ship.

AUXILIARY SWITCHBOARDS.

These 12 auxiliary switchboards are placed directly opposite each other, port and starboard, and cross-connecting cables are fitted so that, in the event of one section failing, the supply can be maintained from the other side. It should be mentioned here that, as the motors are only used intermittently, there is always sufficient surplus carrying capacity in the cables to provide for emergencies of this nature, thus guarding against any total extinction of the light.

The auxiliary switchboards are fitted in fireproof chambers, principally on the main deck. The switches are single pole, and the fuses double pole—Mr. Lackie's patent zinc fuse—which breaks circuit with a minimum flash. Each board is provided with a spare panel containing spare fuses ready at a moment's notice.

BRANCH CABLES AND WIRES.

From these auxiliary switchboards vulcanized rubber cables are carried in wood casings to section fuse boxes, which again provide distributing boxes at convenient positions for supplying the lights, the wires being run without joints. It will be

noticed from Figs. 4 and 5 that these cables running from the main deck to the different sections above are like the trunk of a tree, with branches spreading out to the different decks. Special precautions were taken to keep all positive and negative wires in separate grooves.

In the corridors the casings are arranged as shown in Fig. 6, so that all wires are accessible at all times. In all the rooms of the ship the frieze forms a covering to the electric casings. A special feature of this is to be seen in the lounge, library and smoking room, and all over the ship the wires are accessible, Figs. 7 and 8. No fuse boxes have been fitted, but all fuse panels are built in specially-arranged recesses in the panelling, the panel itself forming the door; a door is also fitted behind for access to the wires. Inside the door a tablet or card is fitted, giving information of what each branch supplies, with size of fuse.

In the wiring of engine and boiler spaces and other parts of the ship exposed to rough work, the protection of the branch wires calls for special treatment. Some engineers think screwed-iron conduit or galvanized-iron tubes are most suitable, but experience has proved that tubes sweat and retain condensed moisture which very soon destroys the best insulation. The best results are obtained with parallel twin conductors, each conductor being separately insulated with pure rubber and vulcanized rubber, braided and bound together, then sheathed with an outer armor of galvanized-iron wire.

This system of armored twin conductors has special advantages for engine rooms and other exposed parts. It is compact, requires less space, and has as strong a mechanical protection as an iron tube, but does not harbor moisture about the insulation as in the case of tubes. When well coated with paint the armoring is further protected from corrosion. It is watertight and fireproof, has no soldered joints, and is always accessible.

In addition to the lighting and power circuits, there are single-core and multiple-core cables for electric bells, telephones, fire alarms, electric clocks, and the Stone Lloyd sys-

tem of indicating the position of watertight doors. These cables are too numerous to give in detail. There are over 200 miles of wire fitted, the copper in which weighs over 100 tons.

ELECTRIC LIGHTING.

There are over 6,300 lamps distributed over the ship, fitted to pendants, electroliers and brackets of various designs to suit the furnishings of the respective rooms. In the public rooms and state rooms the fittings are of a most handsome design, and the arrangement of concealed lamps for lighting the dining-saloon dome gives a beautiful sunlight effect, while other compartments are brilliantly illuminated with beautiful crystal fittings. A special feature throughout has been to design the fittings so as to obtain reflected lighting from the ceilings as well as from the lamp itself.

ELECTRIC POWER.

Electrical transmission of power was evidently not thought of when the Cunard Company built the *Servia,* and it will be interesting to follow the latest development in this branch. In every department of engineering the electrical transmission of power has become almost universal, but on shipboard it has made but little progress. In the latest Cunard steamers, however, there has been a decided advancement. In no other steamship, including the most recent German vessels, can be found anything to compare with the electric installation on the *Mauretania.*

The Cunard Company and their engineers realized that if steam were used for auxiliary work the loss through condensation in the enormous lengths of steam pipes would be very great, and also that the annoyance to passengers would be unbearable. They therefore took full advantage of the simple and more economical method of distributing the power electrically throughout the ship.

In this installation there are:—

16 motors aggregating 800 H.P. for forced draft.
28 motors aggregating 276 H.P. for ventilation of machinery space.
18 motors aggregating 400 H.P. for auxiliary machinery in engine room.
16 motors aggregating 52 H.P. for ventilating the ship.
53 motors aggregating 156 H.P. for the thermotanks supplying heated air.
4 motors aggregating 64 H.P. for refrigerating machinery.
2 motors aggregating 16 H.P. for two passenger elevators.
4 motors aggregating 108 H.P. for lifeboat winches.
8 motors aggregating 48 H.P. for electric jib cranes.
6 motors aggregating 78 H.P. for mails and baggage hoists.
6 motors aggregating 20 H.P. for hoists and stores.
2 motors aggregating 10 H.P. for printing machinery.
1 motor aggregating 5 H.P. for wireless telegraphy.
20 H.P. for pantry and kitchen service machinery and hot plates.
80 H.P. for 106 electric radiators for special state rooms, bath rooms and hospitals.

A total of 2,133 H.P. independent of the power for lighting.

The forced draft for the main boilers is supplied by 32 fans arranged in pairs and driven by 16 electric motors of 50 H.P. each; the motors are of the enclosed type, developing the power at 450 revolutions per minute, with the current at 110 volts. The fan impellers are of the single inlet type, being 66 inches in diameter and each capable of delivering 33,000 cubic feet of air per minute, against a water pressure of 3¼ inches on the discharge side when running at 450 revolutions per minute.

Owing to the high temperature in which these motors have to work, a very ingenious arrangement is provided whereby they may be cooled. Situated between the motor at the commutator end and one of the 66-inch fans, is an auxiliary fan with separate casing, the disc being 48 inches in diameter and made of sheet brass. The discharge is connected to the under

side of the motor and plate, the air being circulated round the commutator and armature, and leaving at the opposite end. Each fan is provided with a water gauge and tachometer. Fig. 9 illustrates a forced-draft motor and fan. Each motor is also fitted with a controller or switch capable of regulating the speed in equal increments by field variation from 225 to 450 revolutions per minute. Low voltage and overload automatic releases are fitted to these controllers, giving complete protection to the motors under all conditions.

When running at the lowest speed the approximate output of air from each fan is 17,000 cubic feet per minute, against a water pressure of 1 inch. Each fan room is also ventilated by 8 single-inlet fans 21 inches in diameter, each being driven by a motor of the totally-enclosed type capable of delivering 1,000 cubic feet of air per minute against a water pressure of 1 inch, when running at a speed of 900 revolutions per minute.

The motors are of the four-pole series-wound type, and are each capable of developing normally an output of 5 H.P. when supplied with current at a pressure of 110 volts and running at a speed of 900 revolutions per minute. Each motor is supplied with a controlling panel consisting of a one double-pole quick-break switch, tubular fuses and starting and regulating resistances, the whole being self contained and mounted upon a panel suitable for erection on the bulkhead.

In the engine room the electric motor performs a most important part in the manipulation of the main turbines and other gear. For dismantling the turbines there are six sets of lifting gear, each consisting of a 30-H.P. motor, driving a horizontal shaft above the turbine, coupled to two 7-inch diameter vertical lifting screws and worm gear, by which means the turbine casing or rotor can be lifted in turn, Fig. 10. The weight of the L.P. rotor is about 125 tons and the H.P. rotor 72 tons, and these can be lifted in 30 minutes.

One of the best illustrations of the adaptability and usefulness of electric motors on board ship is to be found in the case of the electrically-controlled sluice valves. There are two 75-inch and two 60-inch sluice valves in connection with the

high-pressure turbine exhaust steam, and in each of these is fitted a 12-H.P. motor operating a worn gear, as shown in Fig. 11. Each is controlled from switches, Fig. 12, on the starting platform, where an index shows the action of the valve. The fact that the valves can be closed in a minute or two by the electric motor, and that it would take four men 2½ hours to close it by hand, shows a remarkable saving in time and labor in favor of the electric motor. Other useful applications of the electric motor in the engine room is the 30-H.P. motors installed for the turning gear, and 25-H.P. motors which drive centrifugal pumps drawing off surplus water from the condensers.

For ventilating the engine room there are ten Sirocco fans of 25 inches diameter, each driven by a 5-H.P. motor; six fans of 30 inches diameter, each driven by a 30-H.P. motor; and four fans of 15 inches diameter coupled to 1½-H.P. motors.

The general heating and ventilating of the ship is maintained by 53 thermotanks, each fitted with a motor-driven fan, the motors varying from 2½ to 4 H.P., making a total of 156 H.P., Fig. 13. Each motor fan supplies a section of the ship with warm or cold air, or, by arrangement of valves on the tanks, the fans can be made to extract the air from various compartments.

DECK WINCHES AND OTHER APPLIANCES.

Electric-power driving is also extensively used for deck winches, passenger hoists, and other appliances to the extent of 270 H.P.

For the passenger lift, two motors of 8 H.P. supply the power to the winding gear, Fig. 14, while other two motors of 15 H.P. supply the power for two 40-cwt. baggage hoists, and two 5-H.P. motors operate two 10-cwt. store hoists, while two more of 1½ H.P. control the two 2-cwt. pantry hoists for conveying food from the kitchen. There are also two mail hoists fitted with 12-H.P. motors.

In addition to these there are four electric jib cranes, each

made to lift 12 cwts., Fig. 15. The lifting motions are operated by a 12-H.P. motor through worm gear, and the slewing motion through worm and spur gearing by a 2½-H.P. motor, the motors being series wound of the enclosed type. These cranes do their work absolutely without noise of any kind, and are conveniently placed on the boat deck for lifting stores, or luggage and mails from tenders that come alongside.

Another important part performed by electric power is the hoisting and lowering of the lifeboats. This work is done by four electric winches placed alongside the lifeboats, Fig. 16. The motors attached to these winches are each of 27 H.P. connected to worm gear running in an oil bath. The rapidity with which the lifeboats can be manipulated, as compared by hand, must be apparent to all.

An interesting application of electric driving is in connection with the refrigerating machinery, Fig. 17.

The two gas compressors are each coupled direct to a 12-pole shunt-wound motor of 35 H.P., giving a constant torque between 40 and 110 revolutions per minute. The armature is provided with two windings which are in series at starting, and by turning the hand-wheel on the switch-gear, the starting resistance is cut out and a variable resistance inserted in the shunt circuit to regulate the speed between 35 and 75 revolutions per minute. By transposing the armature windings from series to parallel connections without resistance, and by inserting the shunt resistance again, the speed can be increased to 110 revolutions per minute. The two brine pumps are operated by shunt-wound motors of 3½ H.P. each.

In addition to the large number of motors already enumerated, there are still a great number of other applications, but time will only permit me to refer to them briefly.

Among these are the motors for driving the printing machine and the Marconi apparatus of 5 and 3 H.P., respectively, and provision is made by having connections on deck for driving winches of 112 H.P. on the quay or in barges. In the galleys and cooking department an electric motor drives a machine capable of making bread for 3,000 people; and in the

cooking ovens there are four vertical spits, driven electrically, capable of dealing with a half-ton of meat at a time; other motors are fitted to knife-cleaning machines, dish-washing machines, circular knives for cutting bacon, potato peelers, whisking machine, freezing machines for making ice cream, and numerous electric hot plates for keeping food warm during service.

TELEPHONE AND ELECTRIC BELL SYSTEM.

Telephone instruments are fitted throughout the first-class state rooms. Having an exchange on board, passengers can converse with one another without leaving their rooms. On arrival in port the exchange is connected to the Liverpool or New York exchange, so that passengers may be in communication with their homes or offices up till the hour of sailing or immediately on arrival.

Another telephone system connects the captain and officers on watch on the bridge with the engine rooms, and crow's nest on the foremast. These consist of Graham's navy-pattern loud-speaking telephones, and are used for docking and steering as well, connections being fitted on the forecastle, in the wheel house aft, and in the steering-gear room at the stern of the ship. For the officers' use there is an intercommunication telephone service fitted, consisting of the Parsons Sloper secret instruments, each officer being able to call up another from his own room.

In addition to the telephone system there is a large installation of electric bells with Gents' patent indicators. In every first-class state room there is a combination fitting of electric-bell push, electric-light switch, connection for portable reading lamp or curling-tongs heater, and electric fans, while a number of special rooms are fitted with electric radiators.

A complete installation of electric clocks is fitted on the magnetic system. In the public rooms and principal entrances and corridors there are fitted, in all, forty-eight clocks, controlled from the master clock, situated in the chart room adjoining the bridge.

There is also a complete electric fire-alarm system. A brass plate and red lamp indicate the position of the alarm push in the corridors, these being connected to indicators in the engine room and the navigating house on the bridge deck. There is also a subsidiary fire-alarm apparatus fitted near the bridge, consisting of a small cabinet into which a number of tubes are led from the various holds, a small electrically-driven fan continually exhausts the air from the tubes, and in the event of a fire it would be easily detected from which hold the smoke issued. A mercury-contact type fire-alarm indicator is also fitted in the case, which, with the rising temperature, rings an alarm bell.

In addition to the ordinary life buoys, there are two special buoys fitted on the bridge deck operated by Martin's electric release gear, which can be operated from the bridge and other positions, on the alarm being raised.

In connection with the Stone Lloyd system of watertight doors, an electric indicator is fitted in the navigating house which shows the position of every watertight door in the ship, Fig. 18. The doors are closed or opened by hydraulic power simultaneously, by the officer in charge moving a handle which operates the control valve. The function of the electric indicator is to show the officer exactly what doors are open or closed. The indicator has a small lamp for each door with wires led to a contact switch at the door which, when the door is closed, completes the lamp circuit and lights the lamp.

Another important fitting on the bridge is Martin's automatic indicator for the navigating lamps, which is shown open and closed in Fig. 19. The indicator controls five lights as shown, each light consisting of a duplicate-filament lamp, one filament being lighted normally. In the event of this filament failing, the armature of a small electro-magnet which is in circuit is released, and falls against an auxiliary contact, which completes a circuit through the remaining lamp filament and through the indicator lamp corresponding to the light affected. Attention is also drawn to the occurrence by an electric horn attached to the indicator. On the officer in

charge pulling a handle the horn ceases to sound, and the electro magnet is inserted in circuit with the second filament; should this latter fail the horn again sounds, and cannot be stopped until the lamp is replaced or switched off. The several lamp circuits are controlled by the slipper switches seen under the indicator, and the latter—as, indeed, all the important apparatus on the ship—is connected through a change-over switch from either the port or starboard feeder systems, thus guarding against a failure in the navigating lights.

In conclusion, I commend to marine engineers and naval architects a closer study of the advantages of electrical power driving for all auxiliary machinery. The question of propelling the ship by electric motors awaits development, but the electrical equipment of the *Mauretania* shows many advantages over the present wasteful system of steam engines.

DESCRIPTION AND OFFICIAL TRIALS OF THE U. S. S. *SALEM.*

BY C. B. EDWARDS, ASSOCIATE.

The *Salem* is a high-speed scout cruiser, built by the Fore River Shipbuilding Co., with hull from Navy Department's designs and propelling machinery from builders' designs.

The contract was signed May 17, 1905, and calls for a vessel having a trial displacement of 3,750 tons and to fulfill the following trial requirements:

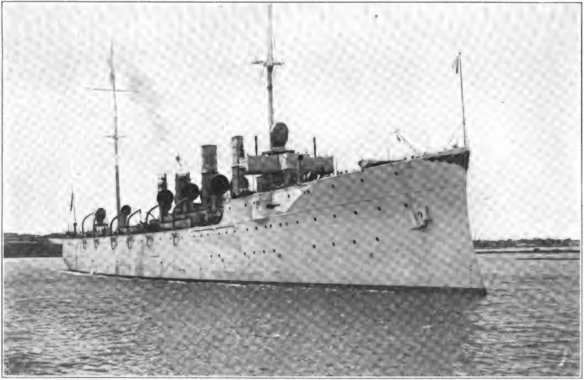
1. A full-speed trial for four hours at sea at not less than 24 knots.

2. An endurance and coal-consumption trial at sea for twenty-four hours at not less than 22½ knots.

3. An endurance and coal-consumption trial at sea for twenty-four hours at not less than 12 knots.

The speed in all the above trials was to be measured by the average revolutions of the propellers as determined by a standardization trial on a measured mile previous to the sea trials. On the 22½-knot endurance run the contract also requires that the vessel make 1.8 knots per ton of coal.

The *Salem* is one of the three sister ships contracted for at the same time, the other two being the *Birmingham*, built by the same company, and the *Chester*, built by the Bath Iron Works. The *Salem* is propelled by twin-screw Curtis marine reversible turbines, the *Birmingham* by twin-screw reciprocating engines, and the *Chester* for four-screw Parsons turbines, while the lines and other machinery of all three vessels are practically identical. This makes the trials of these three vessels especially interesting on account of giving direct comparisons of these three systems of propelling engines.



U. S. SCOUT CRUISER "SALEM."

HULL.

The vessel carries an armament of two 5-inch and six 3-inch guns and two 21-inch submerged torpedo tubes, and has 2-inch nickel-steel protection on the sides in way of machinery spaces. The principal dimensions are as follows:

Length between perpendiculars, feet	420
over all, feet and inches	423-2
on L.W.L., feet	420
Breadth, extreme, feet and inches	47-0¾
molded, feet and inches	46-8
on L.W.L., feet and inches	46-8
Draught, trial, at 3,750 tons, feet and inches	16-8½
fully loaded, at 4,710 tons, feet and inches	19-2½
Depth molded main deck, M. S., feet and inches	36-5 1/16
Displacement per inch at L.W.L., tons	30.8
Area of midship section, trial draught, square feet	566
L.W.L. plane, trial draught, square feet	12,960
wetted surface, trial draught, square feet	19,900
Capacity of coal bunkers at 43 cubic feet per ton, tons	1,358
reserve feed-water compartments, tons	116½
Block coefficient, trial draught	.40
Midship coefficient, trial draught	.72
L.W.L. plane, trial draught	.66

MAIN ENGINES.

The propelling engines consist of two Curtis marine reversible turbines, one on each of the two shafts. The turbines have a designed aggregate of 16,000 brake horsepower at 350 r.m.p., with 250 pounds steam pressure in chest. Each turbine has a pitch diameter of the wheels of 120 inches and is of the 7-stage type, having seven ahead wheels and two reverse wheels; each wheel has three rows of moving buckets, except the first ahead wheel, which has four rows.

These turbines are identical with those of the Southern Pacific Co. steamer *Creole*, described and illustrated with drawings in the author's paper in "JOURNAL A. S. N. E.," No. 3, of Vol. XIX, except that here the areas of the nozzles are double those of the *Creole*, as the designed power is twice as much, and provision must be made for twice the volume of steam to flow.

The turbines are located in separate engine rooms, the starboard room being forward of the port, as the vessel is not wide enough to permit both being arranged athwartships. Each turbine is controlled by two operating levers which admit steam through balanced throttle valves to either the ahead or astern steam chest. The arrangement of engine room is shown in Fig. 2. Each turbine has a thrust bearing with horseshoes. The thrust shaft is 12 inches in diameter, and has twelve collars 19 inches in diameter and 1⅜ inches thick.

PROPELLERS.

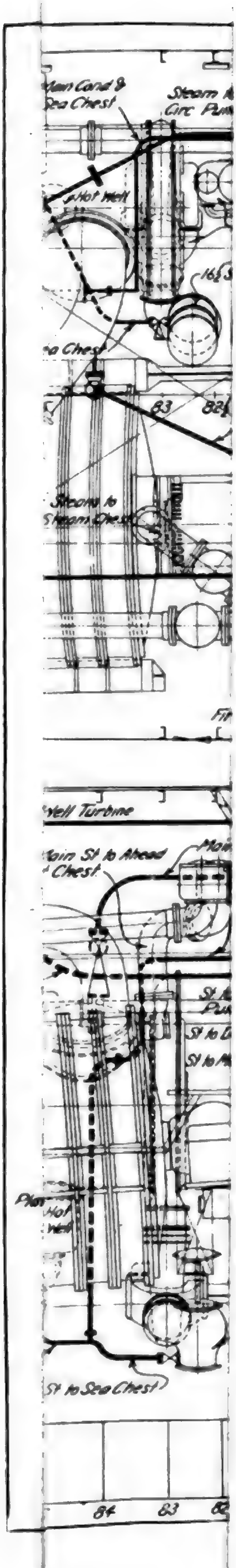
The contractors made four different sets of propellers, which were all carefully tried on the measured mile and the best set selected for the official trials. The design finally used was of the 3-bladed, cast-solid, twin-screw type, of the following dimensions:

Diameter, feet and inches	9-06
Pitch, feet and inches	8-08¾
Pitch, ratio	.916
Developed area, square feet	43.7
Projected area, square feet	36.8
Developed area, ratio	.617
Projected area, ratio	.52
Diameter of hub, inches	24
Immerson of upper tip at load draught, inches	80
Turn outboard.	

BOILERS.

Twelve boilers of the Fore River type are installed in three separate compartments, as shown in Fig. 3. The boiler data are as follows:

Working pressure, pounds per square inch	275
Test pressure, pounds per square inch	400
Length of grate, feet and inches	7-03
Width of grate, feet and inches	8-00
Grate surface one boiler, square feet	56
Heating surface one boiler, square feet	3,166
Total grate surface, square feet	696
heating surface, square feet	37,992



Main Cond & Sea Chest
Steam
Circ Pum
Hot Well
Sea Chest
83
Steam to Steam Chest
Well Turbine
Main St to Ahead Chest
St to
St to
Hot Well
St to Sea Chest
84
83

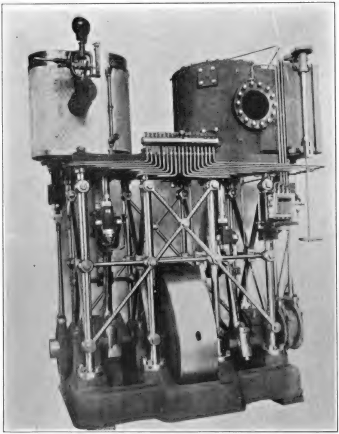


Fig. 3.—DRY VACUUM PUMP.

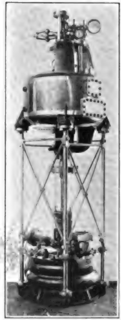


Fig. 4.—WET VACUUM CENTRIFUGAL TURBINE HOT-WELL PUMP.

Ratio	54.6
Tubes, No. 11 B. W. G., diameter outside, inches	$1\frac{1}{8}$
per boiler, 34 rows of 43 each, making a total of	1,462
Area of smoke pipes handling two boilers, square feet	17.6
four boilers, square feet	34.9
Height of smoke pipes above grate, feet	63

MAIN CONDENSERS.

Each turbine has located at its side one Worthington type horizontal cylindrical surface condenser. The cooling water passes through twice, coming in through the lower and going out through the upper half of the tubes. At the bottom of each condenser is a baffle plate, which separates the condensed steam from the entrained air. The condensed steam flows to a hotwell consisting of a casting fastened to the outside of the shell and then to the suction pipe of the centrifugal wet hotwell pumps. The air flows out through a separate nozzle on the condenser shell to the dry-air pump.

Cooling surface, square feet	9,460
Number of tubes	4,448
Length of tubes, feet and inches	13-2
Outside diameter of tubes, inch	$\frac{5}{8}$
Thickness of tubes	No. 16 B. W. G.
Two exhaust-steam inlets, diameter each, inches	42

DRY-AIR PUMPS.

Each turbine has one Blake rotary vertical dry-air pump (as shown in Fig. 3), having one steam cylinder and one air cylinder, each double acting. Each cylinder has a connecting rod and crank, operating on the same crank shaft, which carries a flywheel between the two cranks.

Steam cylinder, diameter, inches	10
Air cylinder, diameter, inches	24
Stroke of both, inches	18

CENTRIFUGAL HOTWELL PUMPS.

The condensed steam is drawn out of each condenser by a Worthington vertical, 2-stage, centrifugal, hotwell pump, di-

rect driven by a small Curtis turbine 27 inches in diameter, 2-stage, as shown in Fig. 4. The pump has 4-inch suction and discharge, and runs at 1,200 r.p.m. designed.

MAIN CIRCULATING PUMPS.

Each main condenser has one double-inlet centrifugal circulating pump, direct driven by a compound engine. The pumps have 16½-inch-diameter discharge nozzles, and are designed to deliver 11,000 gallons of water per minute each at 360 r.p.m.

MAIN FEED PUMPS.

In each engine room there is one Blake vertical simplex feed pump, $15 \times 10 \times 15$, with suction from feed tanks and discharge through a grease extractor to main feed line.

AUXILIARY FEED PUMPS.

Three auxiliary feed pumps are installed, one in each fireroom. Each is a Blake vertical simplex, $9 \times 6 \times 12$.

FORCED-LUBRICATION SYSTEM.

The main turbine bearings and thrust blocks in each engine room are provided with a separate forced-lubrication system. The oil is first delivered by a pair of $4 \times 6 \times 6$ vertical simplex oil pumps to a 100.gallon distributing tank in the engine hatch, and from there flows to the bearings. The drain from the bearings goes to a 110-gallon settling tank on the inner bottom, which is provided with cooling coils taking cooling water from the main circulating pump.

FORCED-DRAFT FANS.

Six Sturtevant fans are installed for forced draft on the closed-fireroom system, being two to each stoke hold. Each fan is 66 inches diameter and 24 inches width at tips of blades, and is of the double-inlet type, with 42-inch-diameter intakes, and is driven by a double engine, 6×6.

FEED-WATER HEATERS.

There are two Wheeler vertical feed-water heaters, one being installed in each engine room. Each has 600 square feet of heating surface composed of 679 tubes, $\frac{5}{8}$-inch diameter, 5 feet 7 inches long and No. 16 B. W. G. These heaters are of the pressure type, with the feed water passing through the inside of the tubes and the auxiliary exhaust steam being piped to the casing and surrounding the tubes. The condensation is piped to the condenser and also to the feed tank.

FEED AND FILTER TANKS.

In each engine room, under the main condenser, there is a galvanized-iron feed and filter tank of about 1,500 gallons capacity. The filter compartment is of the usual construction and has a capacity of about 300 gallons. Loofa sponges are used for filtering.

AUXILIARY CONDENSER.

An auxiliary condenser is located in the forward engine room, having 600 square feet of cooling surface composed of 566 tubes $\frac{5}{8}$-inch diameter, 6 feet 8 inches long, and No. 16 B. W. G. It has a combined air and circulating pump $6 \times 10 \times 10 \times 12$.

EVAPORATING PLANT.

An evaporating and distilling plant, having a capacity of 16,000 gallons of fresh water per day, is installed. There are four Williamson evaporators, each having 223 square feet of heating surface of 2-inch brass tubes, and four distillers each having 80 square feet cooling surface of $\frac{5}{8}$-inch tinned-brass tubes. There are two distiller circulating pumps $10 \times 10 \times 2$, horizontal simplex, one evaporator feed pump $4\frac{1}{2} \times 5 \times 6$, vertical simplex, and one fresh-water pump $4\frac{1}{2} \times 5 \times 6$ vertical simplex.

REFRIGERATING PLANT.

Two Allen dense-air ice machines, of one ton per day capacity each, are installed, having an 8×8 steam cylinder.

ELECTRIC PLANT.

The dynamo room contains three 32-kw. General Electric generating sets delivering direct current at 125 volts. The driving engines are cross-compound vertical, $7\frac{1}{2} \times 12 \times 8$, and run at 400 r. p. m. There is a separate dynamo condenser of 200 square feet of cooling surface having a combined air and circulating pump, $6 \times 8 \times 8 \times 12$. The switchboard is located in the dynamo room.

The following electric auxiliaries are installed:

4 30-H.P. compound-geared deck winches.
3 5-H.P., 8,000-cubic feet hull-ventilation fans.
5 $1\frac{3}{4}$-H.P., 2,500-cubic feet hull-ventilation fans.
1 $1\frac{1}{2}$-H.P., fresh-water triplex pump, 30 gallons per minute.
1 1-H.P. dough mixer.
1 10-H.P. workshop motor.
1 2-H.P. dish washer.
1 $\frac{3}{4}$-H.P. potato peeler.
6 $\frac{1}{4}$-H.P. portable ventilating sets.
6 $\frac{1}{8}$-H.P. bracket fans.
30 $\frac{1}{12}$-H.P. desk fans.
2 60-inch searchlights.
1 80-H.P. torpedo air compressors.
4 3-H.P. ammunition hoists.
22 arc lights.
778 16-candlepower incandescent lights.

Complete interior communication systems, including a telephone central station in chart house, with 18 telephones, are installed.

Wiring is installed, partly in conduit and partly open, on porcelain insulators.

STEERING GEAR.

A Williamson steam-steering engine drives the usual Navy standard right-and-left-hand screw gear. There are two hori-

zontal steam cylinders, 12 × 10. The controlling valve of the engine is operated by wire-rope transmission from steering wheels in chart house and on bridge, and a steering wheel is mounted on the engine. Hand-steering wheels are also installed in the steering-engine room.

ANCHOR ENGINE.

The windlass has two wildcats on vertical shafts driven by two wormwheels meshing with one worm on an extension of the engine crankshaft. The engine is of the double vertical type.

MISCELLANEOUS AUXILIARIES.

2 engine-room fire and bilge pumps, Blake vertical simplex, $10 \times 8\frac{1}{2} \times 12$.
1 reserve feed-tank pump, Blake vertical simplex, $3\frac{1}{2} \times 4 \times 4$.
3 fireroom fire and bilge pumps, Blake vertical simplex, $12 \times 8 \times 12$.
3 ash hoists, Williamson, $4\frac{1}{2} \times 4\frac{1}{2}$.
3 hydraulic ash ejectors, one in each fireroom.

POWER OF AUXILIARIES.

While at the dock the various auxiliaries were indicated and curves of I.H.P. plotted. The following are here given:

Fig. 5, forced-draft fans; Fig. 6, main circulating pump; Fig. 7, dry vacuum pump; Figs. 8 and 9, hotwell pump. All other auxiliaries are the same as those installed on the U. S. S. *Birmingham*, curves for which are given in paper by Commander Theo. C. Fenton, in "JOURNAL A. S. N. E.," Vol. XX, No. 3, August, 1908, and the same curves were used on the *Salem*.

BUILDERS' TRIALS.

Before leaving the builders' yard four complete sets of propellers were made. All except the No. 1 set were of the cast-solid type. Each set was tried by a run across Massachusetts Bay and a standardization on the Provincetown measured

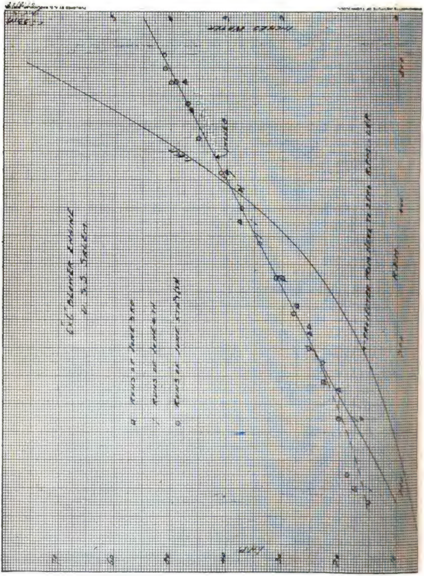

6"x6" BLOWER ENGINE
U. S. S. SALEM.
RUNS OF JUNE 3RD
RUNS OF JUNE 4TH
RUNS OF JUNE 5TH & 6TH
PROJECTED FROM HERE TO ZERO R.P.M.
R.P.M.
I.H.P.

Fig. 5.

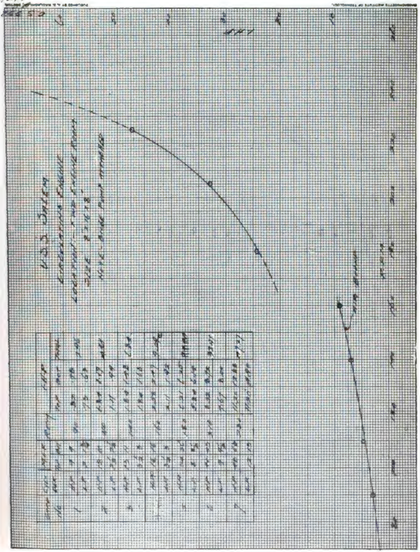

U.S.S. Salem
Circulating Engine
Location – Engine Room
Note – Bilge Pump Attached
I.H.P.
R.P.M.
10
20
30
40
50
60
80
100
120
140
160
180
200
220
240
260

Fig. 6.

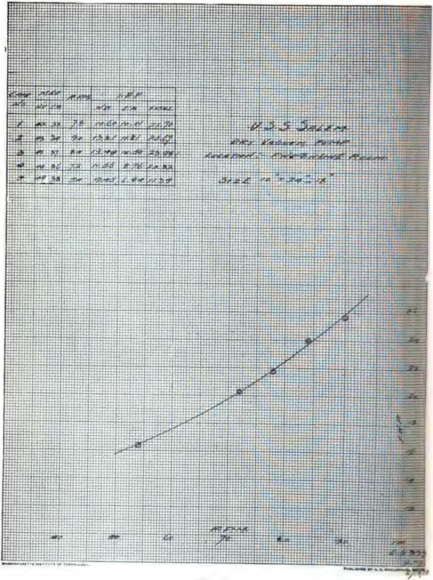


Fig. 7.

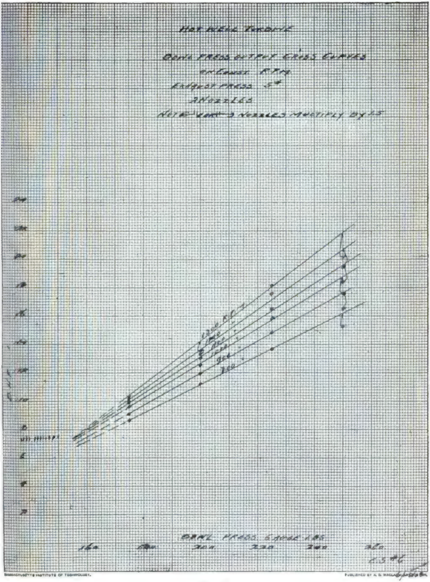

HOT WELL TURBINE
BOWL PRESS OUTPUT CROSS CURVES
ON CONST. R.P.M.
EXHAUST PRESS. 5#
2 NOZZLES
NOTE—FOR 3 NOZZLES MULTIPLY BY 1.5
24
22
20
18
16
14
12
10
8
6
4
2
1200 R.P.M.
1000
900
BOWL PRESS. GAUGE LBS.
160
180
200
220
240
260
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
PUBLISHED BY A. D. MACLACHLAN, BOSTON.

Fig. 8.

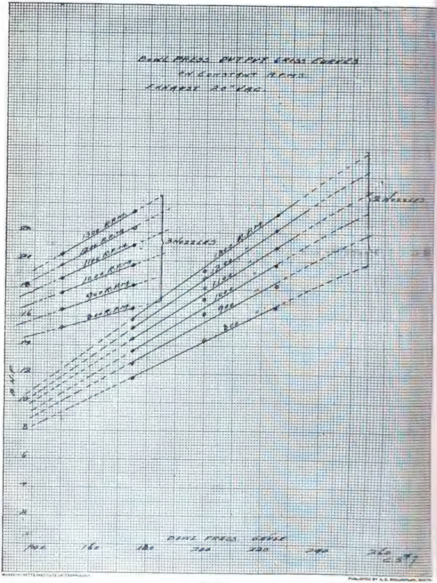

BOWL PRESS. OUTPUT CROSS CURVES
ON CONSTANT R.P.M.S.
EXHAUST 20" VAC.
1300 R.P.M.
1200 R.P.M.
1100 R.P.M.
1000 R.P.M.
900 R.P.M.
800 R.P.M.
3 NOZZLES
1300 R.P.M.
1200
1100
1000
900
800
2 NOZZLES
22
20
18
16
14
12
10
8
6
4
2
BOWL PRESS. GAUGE
140
160
180
200
220
240
260
C.S.T.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Fig. 9.

mile. The vessel returned to the Boston Navy Yard after each trial, and went into drydock to have the propellers changed. The second set tried proved to be the best, and was refitted after the completion of the trials.

The vessel left the builders' yard on June 3, 1908, and completed the four trials on June 12, 1908, in an elapsed time of nine days, including two days spent in drydock for cleaning and painting.

Immediately after these trials request was made to the Department for official trial. The Board of Inspection and Survey came on board the vessel at Rockland on June 22d, and all the official trials were finished July 1st, in an elapsed time of nine days.

OFFICIAL TRIALS.

The vessel was first standardized on the measured mile at Rockland, then the four-hour full-speed run was made, followed by the twenty-four-hour run at 12 knots, and finally the twenty-four-hour run at 22½ knots.

STANDARDIZATION.

The mile runs were made in groups of three, at approximately 12, 14, 16, 19 and 23 knots, and a group of five runs at 26 knots. Each group of three runs was averaged by multiplying the middle run by two and dividing the total by 4; the five high runs were averaged similarly in groups of three and the mean of these two averages taken. The knots-revolution curve was drawn through these averaged points.

The brake horsepower developed by the turbines was measured by Denny-Johnson torsion meters, operated by the Trial Board, and also by a Fottinger torsion meter, operated by the contractors. These two measurements check each other within 2 per cent. at full power; the Fottinger meter readings are used in this report.

The observed results in each run are given in the following table:

STANDARDIZATION RUNS, JUNE 23, 1908.

Run No.	Knots.	Nozzles open.	R. P. M.			Main, Starboard.	Steam port.	Chest.		First stage.		Exh. shell vacuum.		Condenser vacuum.		Torsion meter reading.
			Stbd.	Port.	Mean.			Stbd.	Port.	Stbd.	Port.	Stbd.	Port.	Stbd.	Port.	
1	14.60	3	192.8	195.9	194.3	251	254	230	250	11.5	13.0	28.8	27.8	28.9	28.2	2.59
2	13.33	3	187.5	193.0	190.2	263	264	208	235	11.5	13.0	28.8	28.3	28.9	28.5	2.60
3	14.06	3	185.0	194.0	189.5	265	265	201	210	11.5	13.0	28.8	28.1	28.9	28.5	2.53
4	15.48	4	223.2	225.3	224.2	260	268	246	265	17.5	17.0	28.8	28.2	28.8	28.6	3.73
5	16.86	4	223.3	219.1	221.2	250	250	237	250	18.0	18.0	28.8	28.0	28.8	28.3	3.72
6	15.319	4	223.1	223.4	223.2	263	256	246	254	18.0	19.0	28.6	27.7	28.9	28.2	3.75
7	26.201	19	368.5	366.7	367.6	265	262	260	253	83.0	76.0	27.2	27.2	28.2	28.1	11.84
8	25.193	19	379.0	377.1	378.0	258	257	255	250	92.0	84.0	27.0	27.0	28.1	28.1	12.68
9	26.886	20	383.3	381.6	382.4	263	260	259	250	97.5	84.0	26.9	26.9	28.1	28.0	13.33
10	25.334	20	382.6	381.1	381.8	259	255	254	248	95.0	88.0	26.6	27.0	27.8	28.0	13.08
11	26.608	20	377.5	377.3	377.4	255	249	255	247	93.0	87.0	27.3	26.9	28.1	28.0	12.66
12	22.486	11	315.4	327.5	321.4	266	265	245	265	50.0	52.0	27.4	27.6	28.1	27.6	7.48
13	23.407	11	314.2	317.8	316.0	268	270	242	243	49.0	48.0	28.6	27.0	28.2	27.5	7.60
14	21.752	11	311.4	308.7	310.0	255	253	230	245	47.0	51.0	28.0	27.3	28.3	27.8	7.56
15	19.945	7	266.1	269.6	267.8	260	265	235	245	30.0	34.0	27.2	27.5	27.4	27.6	5.16
16	18.907	7	264.2	270.6	267.4	253	253	232	250	29.8	33.0	27.4	27.5	27.5	27.6	5.14
17	19.262	7	263.2	261.1	262.2	242	248	239	245	29.8	31.0	28.6	25.9	28.7	26.1	5.32
18	11.956	3	169.8	168.1	168.9	270	272	181	190	11.5	11.5	28.5	28.0	28.6	28.2	2.13
19	12.27	3	166.9	163.2	165.0	234	236	177	190	11.0	11.5	28.5	27.7	28.5	28.0	2.29
20	12.30	3	171.4	173.2	172.3	252	230	177	208	11.0	12.5	28.6	27.5	28.5	27.7	2.23

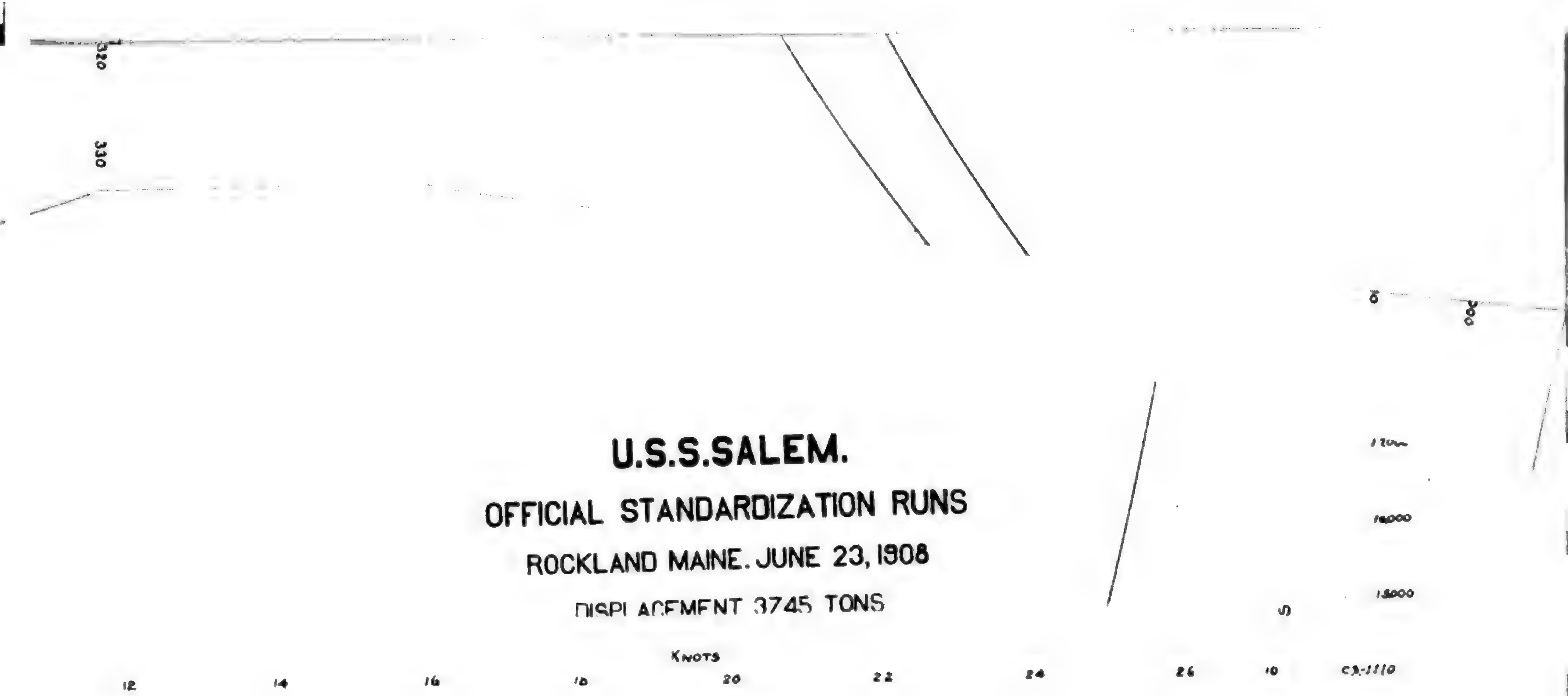

U.S.S.SALEM.
OFFICIAL STANDARDIZATION RUNS
ROCKLAND MAINE. JUNE 23, 1908
DISPLACEMENT 3745 TONS
KNOTS
12
14
16
18
20
22
24
26
330
320
15000
16000

Fig. 11.

The above results are plotted as curves in Figs. 10 and 11, the effective H.P. curve being taken from the model tank results and is without appendages.

RUNS IN OPEN SEA.

After the standardization the three different straight-away open-sea runs as previously given were made, and the speed of the vessel on each taken from the average revolutions of the propellers on the above standardization curve of knots and revolutions.

The following table gives the final average results of the three runs:

Item.	4-Hour, full power.	24-Hour, 22½ knots.	24-Hour, 12 knots.
Date, 1908	June 25.	June 26, 27.	June 30.
Average speed of vessel	25.946	22.53	11.93
Pressures:			
Boilers, pounds, gauge	274.5	255.7	219.6
Throttle valves, pounds, gauge	258.5	246.1	212.0
Steam chest, pounds, gauge	253.0	240.5	162.0
First stage shell, pounds, gauge	77.0	49.0	5.1
Exhaust chamber, inches mercury	26.7	28.4	27.9
Condenser, inches, mercury	27.8	28.65	28.7
Air pressure in fireroom, maximum	4.7	2.6	1.1
average	4.1	2.01	0.84
Temperatures, degrees Fahrenheit:			
Injection	56.5	57.0	58.0
Discharge	98.0	84.8	81.5
Hotwell	97.0	76.2	68.0
Feed water	178.0	180.6	181.0
Engine-room working platform	90.0	92.0	91.0
Firerooms working level	100.0	92.0	97.0
Smokestacks	764.0	602.0	537.0
Outside air	71.0	68.0	68.0
Revolutions, or double strokes, per minute:			
Main turbines	378.3	312.5	164.1
Dry-air pumps	68.0	50.5	40.5
Hotwell pumps	1,329.0	1,320.0	1,316.0
Circulating pumps	365.0	275.0	125.5
Main feed pumps	34.0	25.5	16.0
Dynamo engines	400.0	400.0	400.0
Forced-draft blowers	512.0	345.0	252.0
Distiller-circulating pumps	16.0	34.0	...
Slip of propellers	20.28	16.17	15.48

Item.	4-Hour. full power.	24-Hour. 22½ knots.	24-Hour. 12 knots.
Power:			
Main turbines, B.H.P.	19,200.0	9,340.0	1,360.0
Dry-air pumps, I.H.P.	39.0	32.0	28.0
Hotwell pumps, I.H.P.	49.0	48.0	31.0
Circulating pumps, I.H.P.	371.0	196.0	25.0
Main feed pumps, I.H.P.	143.0	96.0	26.0
Total engine auxiliaries, I.H.P.	602.0	372.0	110.0
Dynamo engines, I.H.P.	35.0	35.0	35.0
Forced-draft blowers, I.H.P.	450.0	126.0	36.0
Distiller-circulating pump, I.H.P.	5.0	23.0	6.0
Fire and bilge pump, I.H.P.	...	1.0	2.0
Steering engine, I.H.P.	5.0	5.0	5.0
Total I.H.P. all auxiliaries	1,097.0	562.0	194.0
Equivalent I.H.P. of main turbines	21,120.0	10,274.0	1,496.0
Grand total all I.H.P.	22,217.0	10,836.0	1,690.0
Coal:			
Total coal burned per hour, pounds.	38,502.0	18,485.0	4,051.0
Per square foot of grate per hour, pounds	55.32	26.56	17.46
Per B.H.P., main turbines, pounds	2.01	1.97	2.98
Per I.H.P., main turbines, per hour, pounds	1.81	1.78	2.68
Total I.H.P. per hour, pounds	1.73	1.70	2.40
Knots per ton of coal	1.51	2.73	6.6
Water:			
Pounds per hour per B.H.P., main turbines only	14.74	15.85	26.13
General:			
Mean displacement, tons	3,751.0	3,753.0	3,760.0
Trim, inches	5¾ by stern	8¾ by stern	1$\frac{1}{16}$ by bow
Course direction	...	E.N.E.	E.N.E.
	W.S.W.	W.S.W.	W.S.W.
Wind direction	W.S.W.	Variable	Variable
Force	2	2 to 3	Light
Sea	Smooth	Smooth	Smooth

SPEED BY HOURS ON A FOUR-HOUR RUN.

1 hour	26.00 knots.
2 hours	26.01 knots.
3 hours	25.98 knots.
4 hours	25.85 knots.

In the above table the equivalent I.H.P., corresponding to the actual B.H.P., of the main turbines as measured, is based on 10 per cent. of friction in an equivalent reciprocating engine.

The water rate per B.H.P., of main turbines above given was measured on the starboard turbine only, by means of temporary measuring tanks installed by the contractors, and the results given are for the portions of the runs when the boilers were steaming quietly without priming.

On account of reserve feed water, taken on in Boston Harbor after the end of the four-hour trial, being impregnated with cement sediment due to tank of the water barge being newly cemented, the boilers primed considerably during the later trials. This priming caused no trouble in the operation of the turbines, which simply slowed down somewhat whenever any water came over.

The coal used gave the following analysis:

Moisture, per cent	3.04
Volatile matter, per cent	18.59
Fixed carbon, per cent	70.94
Ash, per cent	7.43
	100.00
Sulphur	.58
B. T. U. per pound	14,227.0

MANEUVERING TRIALS.

While going at full speed ahead the engine telegraphs were suddenly thrown to full speed astern with the following results:

Begin to back: Port, 42 seconds; starboard, 54 seconds.

Full speed astern: Port, 1 minute 30 seconds; starboard, 1 minute 53 seconds.

From full speed astern to full speed ahead the results were:

Begin to go ahead: Port, 15 seconds; starboard, 25 seconds.

Full speed ahead: Port, 1 minute 4 seconds; starboard 1 minute 33 seconds.

COMPARISON TO RECIPROCATING ENGINE.

The following table compares the principal economy results of the *Salem* with the corresponding figures of the *Birmingham*, which is a sister vessel and of the same construc-

tion in every respect, except that the main propelling engines are of the usual reciprocating type.

Item.	*Salem.*	*Birmingham.*	*Salem.* Gain pr. ct.
Coal per equivalent I.H.P. of main engine per hour, pounds:			
At full power	1.81	1.92	6.07
22½ knots	1.78	1.91	7.3
12 knots	2.68	2.89	7.83
Knots per ton of coal:			
At 22½ knots	2.73	2.47	9.52
12½ knots	6.6	5.965	9.62

It is to be noted that in the above comparison the *Birmingham* developed on the full-power trial an average of 15,540 I.H.P., while the *Salem* developed 19,200 B.H.P., or about 35 per cent. more power, and even at this extra forcing had the better economy. It is also especially noticeable that at the low cruising speed of 12 knots the turbine vessel showed an increased economy gain.

NOTES.

EXTRACT FROM ANNUAL REPORT OF THE CHIEF OF BUREAU OF STEAM ENGINEERING, FOR FISCAL YEAR 1908.

Instruction of Young Line Officers in Engineering.—It is greatly to be deplored that the important and satisfactory work of the Bureau's school for instruction in engineering had to be discontinued for want of officers to be instructed. No new officers have been ordered during the past year and the very satisfactory organization, which had been almost perfected during its three years of existence, has been broken up. Although the number of officers under instruction was always too small, it was infinitely better to instruct these few than none at all.

The need for line officers specialized in engineering has greatly increased and will continue to increase, and one year at least for making these specialists has been lost.

The necessity of officers specializing in engineering was clearly shown in the report for 1907 of my predecessor. I can add to that only my hearty approval of the statements made there, and the firm conviction that the sooner the course of instruction is reestablished the better will the needs of the Navy be satisfied and its efficiency be increased.

It is urgently recommended that the Bureau's course of instruction of young line officers be not only resumed, but that the number of officers detailed for instruction be increased. To interrupt this method of imparting the special engineering knowledge so necessary to the line officer in a modern navy would appear to be a step backward, and, if continued, one that will result in serious detriment to the technical training of this body of officers.

That the experience and knowledge of the few remaining officers for engineering duty only should be utilized in instructing those line officers who are to take over their work

would seem to need no argument, yet the practice in the Navy, except in a very few cases, is directly the opposite. In navy-yards, at inspection duty, and in designing, the officers for engineering duty only practically do the duty alone, but few young officers being assigned to learn the work under them, and to receive the benefit of their experience and knowledge.

Consolidation of Shops at Navy Yards.—During the past year all pattern, copper and foundry work at the larger eastern yards has been consolidated under this Bureau, and the system has now been in operation long enough to show that it will result in increased efficiency and in economy of operation to the Government, and that after the various shops have been thoroughly arranged to meet the new conditions there will be still further improvement in this direction. It is therefore recommended that the system of consolidation adopted for the eastern yards be applied also to those of the west coast.

Officers for Engineering Duty.—It is with regret that I have to invite the attention of the Department to the unsatisfactory condition as regards the number of officers assigned to duty under this Bureau. This condition was commented upon in the reports of my predecessor, and suggestions made for its improvement, but without avail. The condition is rapidly becoming worse, and the Bureau is now seriously handicapped in its work by the lack of officers for engineering duty, and also by the lack of experience of some of the officers who have been so assigned. It is recognized that the limited number of officers available for the general duties of the line is responsible for this condition, but engineering in the Navy has now reached such a point that two things must be done: (1) for temporary relief, at least twenty officers of the grades of lieutenant-commander and lieutenant should be ordered at once to shore duty connected with this Bureau, and (2) a fixed policy should be adopted of assigning permanently a certain number of officers to engineering duty only, such assignment to begin upon entering the list of lieutenants, and officers so assigned to perform shore duty only, after reaching the grade of commander.

There is a vast field for improvement in the administration of the huge machinery installations in the United States Navy; there are many problems of efficiency and economy which can be solved, notably coal and oil consumption; the reduction of expense of a ship coming to a navy-yard for repairs; by a closer and better supervision of machinery details, and which can be gained by a higher and better skilled technical knowledge, and lastly greater economy in navy-yard management. The opportunities for improvements in the field above mentioned can be obtained only by a more extended performance of engineering duty by officers below the rank of commander of the branch to which engineering belongs, viz: the line. Especially must some action be taken in the administration and performance of those shore duties required by law in the execution of engineering contracts for machinery of new vessels under construction, for the large volume of repair work at our navy-yards, and for the inspection of material.

That immediate assistance from the general line for engineering duty on shore is absolutely necessary will appear from the following statement of the duties which must be carried on, and the fact that there are now only six line officers, in addition to the thirty-four for engineering duty only, engaged in these duties.

With these requirements confronting the Bureau, the attention of the Department is invited to the existing conditions:

The Navy-yards.—During the past year the engineering departments of the several navy-yards have suffered seriously from lack of officers. In important yards with numbers of vessels under repairs, the head of department is without a single commissioned assistant. In the event of extended illness there is a decided falling off in the discipline and conduct of work during the enforced absence of the head, without a skilled successor to take up and continue properly the thread of work. The engineering work of officers at navy-yards includes the making of estimates for repairs; deciding upon their necessity; preparing designs for alterations and repairs,

and supervising and conducting the work when authorized, both on shore and on the ships.

For the proper performance of these duties there should be a sufficient detail of commissioned assistants to the senior engineer officer of the navy-yard to insure that technical supervision over details without which work will not be properly done nor its cost kept within estimates. That such assistance has not been furnished from young line officers may be inferred from the fact that but four line officers, other than those for engineering duty only, are now doing engineering duty at navy-yards.

Inspection of Machinery for Vessels Under Construction.—At ship-building yards the conditions are even worse, not a single young line officer being on duty there in connection with machinery, although the field is one of the best for instruction and development. The absence of such assistants renders the duties of the inspectors of machinery particularly onerous and their inspection less efficient, and throws on the over-burdened bureau staff a mass of detail which should be disposed of at the building yard. Before the passage of the personnel law, it was the invariable practice to detail one or more junior officers as assistants to the inspector of machinery of vessels under construction. These officers were always detailed with a view to their assignment to these ships upon completion, and by close personal contact with the machinery during the final stages of its assembly on board, and by their presence and observation during the preliminary and full-speed trials, acquired a mass of information about the machinery and the ship in general that was of incalculable value to the Government during the ship's "shaking down" and in the succeeding periods of active service.

Inspection of Material.—Of equal importance with the work at navy-yards and private shipbuilding establishments is that of the inspection of the material that enters into the construction of our ships. While the number of officers engaged in the duty of material inspection is yearly decreasing, the field of material production for naval engineering purposes is con-

stantly enlarging. My predecessors in office, in their annual reports, have recommended the detail of junior officers of the line for this inspection duty, in order that they might have the benefit of the experience of the older officers now on inspection duty, all of whom are well qualified by experience to instruct younger officers in this important duty. This recommendation I now most earnestly repeat.

The Bureau knows that the quality of the engineering material furnished the Navy has been raised through the development of the present system of inspection, and it is urged that this system be not allowed to lapse or to fall below its present high standard. To maintain this material inspection as it should be maintained, young blood is absolutely essential, and the Bureau respectfully and earnestly urges the detail of junior line officers for this duty. This requested detail of young officers should be made at once, because the number of qualified inspectors is decreasing every year, and but for the retention on inspection duty of several retired officers there would be only two commissioned officers to direct the inspection work of eight districts. At present one retired officer has charge of two important districts and another has four districts in his charge. It is evident that it is not possible, in such cases, for the naval inspector to keep that close personal supervision of the work that is so necessary to success. Consolidation of districts would not help matters at all, since then the responsible head becomes merely a traveling overseer, and practically all the actual work of inspection must be left to assistant inspectors who, in many cases, are not familiar with the object for which the material is to be used, a system which the Bureau does not believe to be desirable. The young line officer should be as well acquainted with the manufacture of the materials that go to make up the machinery of our battle ships as he must be with the design and management of that machinery. In fact, the prime requisite for the successful engineer is to know the qualities of the materials he is to use, whether these materials are to be used in ships, guns, armor or machinery. It is equally important that the line officer, the man who is

to manage the finished product, should know the capabilities and the limitation of his materials. This knowledge can be obtained only by actual duty in the inspection of material as it comes from the forge, the foundry, the plate mill or the tube mill.

The Bureau of Steam Engineering.—The work of designing naval machinery, general supervision over repairs to naval machinery, the examination and supervision of machinery plans in detail submitted by contractors engaged in building government vessels, and the collection and arrangement of engineering data of the world's progress in naval engineering, is done at the Bureau of Steam Engineering.

The work of designing is done under the supervision and direction of line officers for engineering duty only, who were members of the former engineer corps, and who have had the benefit of a course in designing machinery at the Naval Academy, with many years of valuable experience afloat in the management of machinery, and on shore in its construction. It would seem that, as the time for this duty to pass to younger officers is rapidly approaching, it is absolutely necessary that a number of these younger officers should be detailed for duty in the Bureau, in order that they may become familiar with the methods pursued and acquire knowledge of this important part of their profession. There are now only two line officers on duty in the Bureau, other than those for engineering duty only, and, from force of circumstances, one of these is engaged in work other than that connected with design.

The engineer-in-chief, from an extended acquaintance with the young line officers of our Navy in their academic instruction, as well as with their practical engineering training both ashore and afloat, is fully cognizant of the fact that they can become good engineers. While the Naval Academy, with its excellent engineering plant for instruction, probably unequaled in any engineering school in the world, is attending to the academic engineering training, and within its limits, to the practical education also, there is yet much to be done in that

post-graduate training which every technical man must receive in the practical and essential details of his profession. Part of this post-graduate training can be obtained, with a resulting advantage to the Government, and enable the Bureau to carry on the authorized duty on shore, by the assignment of the number of line officers asked for above.

Some of the most important duties performed under this Bureau have been enumerated, as stated above, in order to impress upon the Department the necessity for providing now an adequate number of officers properly to perform it. It is and always has been the opinion of this Bureau that the greatest efficiency results when the officers who design our machinery are also the ones who superintend its construction on shore and later its operation at sea, for thus only can they acquire that familiarity with the needs of the service which suggests at once the things to avoid as well as those to adopt. I think it will be generally admitted by officers of the Navy who have given close attention to the subject that the excellence of our ordnance, of our machinery, and of our electrical equipment has been due to the fact that the officers who inspected the material and superintended the construction on shore were the same ones who afterwards at sea supervised the operation of these parts of the ships' equipment. And I believe that if this system is not fully carried out, there will be deficiency in that branch in which such a system is lacking.

That this system may be carried out in full, it is considered imperative that permanent assignment of officers to engineering duty shall be made after a certain length of service. That such permanent assignment was contemplated by the personnel board of 1906, and of which the present Assistant Secretary of the Navy was president, is evident from paragraph 16 of their report, which provides for "those who are now or may become eligible for engineering duty," and from paragraph 23, which reads: "The board, while in favor of the amalgamation of the line and former engineer corps, as provided by the present personnel law, in a general sense, desires to express the opinion that experience shows that some specialization for

the design and inspection of machinery should be created." Further, from the letter of the then Assistant Secretary of the Navy transmitting the report of the personnel board of 1897, and from the hearings before the Committee on Naval Affairs of the House of Representatives, Fifty-fifth Congress, second session, which resulted in the act of March 3, 1899.

In his letter of transmittal, the then Assistant Secretary said:

"The building of engines, like the building of guns or torpedoes, must be done by special officers selected or detailed for the purpose."

And again:

"This is an age of specialization. * * * In time it may very possibly prove desirable to differentiate, less by law than by departmental custom, among the officers at sea, so as to employ each principally along the lines for which he shows the most aptitude, but they must remain line officers, the major part of whose duties are identical; and the engineer must differ from his fellows only in the same manner as the navigator or ordnance expert does."

In the hearing before the naval committee, the then Assistant Secretary of the Navy said:

"My own view is this: That we should, within the Department, by detail, directly reverse the policy that has for some time obtained there, of having every man in turn do every duty, the fact that he has perfomed the duty being considered a reason why he should never perform it again; and, on the contrary, we should, as far as we can, differentiate men after they have passed through the first eight or ten years."

It is this differentiation that the Bureau earnestly recommends for the consideration of the Department. The plan to accomplish this is simple, will cost no money, and requires legislation only so far as to amend the personnel act as follows:

"*Provided,* That the provisions of section 5 of the act of March 3, 1899, shall apply to such line officers as may be assigned to permanent engineering duty by the Secretary of the Navy."

A number of officers have shown marked aptitude for engi-

neering duty, and are now ready and willing to be assigned to engineering duty only, if the opportunity is given them under the above-mentioned conditions. Without such a system, engineering in the Navy must fail, and any deficiency there means as much to the efficiency of the fleet as failure in guns or torpedoes.

LAUNCH OF SUBMARINE "C. 17."

This vessel, the first of the class to be built in one of the Royal Dockyards, was launched on the 13th ultimo at Chatham. The ceremony was of a private character, and the vessel herself had been built under conditions of close secrecy, the shipway being enclosed and all the workmen who have been engaged on her having been sworn not to divulge any information about her. Her dimensions are as follows: Length, 130 feet; beam, 13 feet 6 inches; with a displacement of 313 tons when submerged. The engines are to develop 600 I.H.P., which will give her a speed on the surface of 13 knots.—"Journal Royal United Service Institute."

ACCIDENTS TO SHIPS OF WAR.

A Parliamentary paper, giving the number of ships and other craft of war which have been in accidents since 1st January, 1901, has been issued by the Admiralty. The return states that during the period, 1st January, 1901, to 27th May, 1908, the number of His Majesty's ships and other craft of war which have been in accidents was 442. The number of His Majesty's ships and other craft of war which have been totally lost was 16, including the loss by fire of the *Forte,* coal depot. The loss of picket boat of the *Edgar,* the steamboat and pulling cutter of the *Vernon,* the gig of the *Defiance,* a submarine mining vessel, and the steam cutter *No. 219,* are excluded. The original cost of ships and other craft which have been totally lost, including guns and naval ordnance stores, was £1,951,974. The number of vessels which have

been in accidents, and which have been repaired during the years 1901 to 1906 was: in His Majesty's dockyards, 218; outside His Majesty's dockyards, 60. The number of lives lost as a result of accidents on board His Majesty's ships was 408. The annual amount of pensions and aggregate amount of gratuities awarded to the dependants of those who lost their lives were: pensions, £2,592; gratuities, £3,290.

FRENCH NAVAL NOTES.

The first-class battleship *Verité,* which conveyed the President of the Republic to Reval on his visit to the Tsar, arrived at Brest with the escorting ships of the squadron on its return from this duty on the 6th ultimo; Vice Admiral Boué de Lapeyrère, who has been in command, struck his flag on board the *Verité* the next morning and resumed his duties as Maritime Prefet of the port.

The first-class battleship *Iéna,* condemned for service after the disastrous explosion last year, is being repaired at Toulon to the extent of making her capable of floating, and to be used as a target. It is stated that the firing experiments will include (1) observation of the effects of projectiles fired at close range on the light armor and superstructure; (2) of the effect of bursting shells after penetration at long distances up to 6,000 meters. The program of firing will, however, be elaborated by a committee, to be presided over by Rear Admiral Auvert, composed of a capitaine de frégate, two engineers, a chef d'escadron of artillery, a captain of artillery, and two lieutenants de vaisseau.

In accordance with the recommendation of the Committee appointed to report on the proposal that the Ecole-Navale should be transferred from the *Borda* to a naval college to be built at Brest, Vice Admiral Boué de Lapeyrère (the Prefet Maritime) and a committee have been charged with the duty of selecting a site for the building. The naval school afloat dates back to the year 1827, when it replaced the naval college at Angoulême; thus history repeats itself.

Four thousand officers and men of the *Artillerie* and *Infanterie Coloniale* have been sent as reinforcements to Tonkin during the last few weeks, and it is stated a like number are to be sent towards the end of the present month.

On the 3d ultimo the new submarine *Turquoise* was launched from the Mourillon-Toulon yard, and is the last of the group being constructed at that yard; the other three vessels being the *Emeraude,* now attached to the 1st Channel Flotilla at Cherbourg, and the *Saphir* and *Topaze,* both completing at Toulon. Her dimensions are as follows: Displacement, 390 tons; I.H.P. of motors to be 600; speed, 12 knots; armament, 6 torpedo discharges, and she will carry a crew of 21 men. Like the *Emeraude,* the other three vessels when completed are to be sent to Cherbourg, and attached to the Channel Flotilla.

The submersible *Fresnet,* 398 tons, was launched at Rochfort on 16th June; she is one of the *Papin* class.—"Journal Royal United Service Institute."

FATAL GUN MISHAP ON BOARD THE GUNNERY-SHIP "COURONNE."

A serious mishap, caused by the premature explosion of the charge of a 6.4-inch Q.F. gun during the closing of the breech block, occurred on board the gunnery ship *Couronne* on the 12th ultimo, while at target practice off Salins-d'Hyères, which resulted in six men being killed, seven badly hurt, and fourteen others more or less seriously injured.

It appears that practice had been carried on from the gun —Model 93-97—during the forenoon, an average of six rounds a minute having been fired. The gun had become very hot, and at 11 A. M. practice was interrupted, to be resumed again at 1 P. M. The charge of these guns is in two parts, the cartridge itself and a copper case, containing the primer, an arrangement which has always been considered a very unsatisfactory one. Thirty-four rounds had been fired after the

resumption of the practice, and the breech block was being pushed home, when there was a tremendous burst of flame, and it was blown violently to the rear. The priming, which was being brought up to the gun for the next charge, was ignited, as well as two other charges at the rear of the guns. All the men who were on this part of the deck were struck down by the terrible blast of this hurricane of flame.

Four officers who were in rear of the gun, by some miraculous chance, only received superficial burns, while between Sub-Lieutenant Mouren, who was in charge of the firing, and Midshipman Thévenard, who was taking the time, in the small space of two paces which separated them four men lay dead. Two other officers, who were going through the gunnery course, were thrown down, but only received slight contusions. The outburst of flame set fire to the deck, the flames from the burning of which were visible to other ships lying in the Roads; but there was no panic, and the fire was fortunately soon extinguished. As the *Couronne* is an old wooden steam line-of-battle-ship, and her decks like tinder, had the fire gained a hold, the safety of the ship might well have been endangered.

It is not known what caused the explosion, as the breech block not being home and locked, the primer could not have been ignited by the blow from the striker, and the Committee of Enquiry, which has been sitting, have not yet made their report.—"La Vie Maritime," "Le Moniteur de la Flotte," and "Le Temps."

FATAL GUN MISHAP ON BOARD THE FRENCH ARMORED CRUISER "LATOUCHE-TRÉVILLE."

We regret to have to report another terrible gun accident, which has taken place on board the *Latouche-Tréville,* tender to the gunnery ship *Couronne,* by which thirteen men have lost their lives, and two have been very seriously wounded. Following so soon after the serious accident on board the *Couronne,* this has created something like consternation. The frequency of these accidents is a serious matter for the French

Navy, and most disquieting to the country; more especially because in none of them has an exact and definite reason for the disaster been forthcoming. The hypotheses that have been put forward, however well argued, are not convincing, and this cannot but lead to an uneasy feeling in the minds of all concerned.

This is the fourth serious gun accident that has taken place in the last two years, in connection with the Gunnery School at Toulon, the total casualties in which amount up to the large figure of 28 killed and 42 wounded = 70. The dates and particulars of these accidents are:

20th April, 1906, on board the *Couronne,* 3 killed, 15 wounded.
2d August, 1907, on board the *Couronne,* 3 killed, 6 wounded.
12th August, 1908, on board the *Couronne,* 9 killed, 19 wounded.
22d September, 1908, on board the *Latouche-Tréville,* 13 killed, 2 wounded.

The following account of this last accident, by an officer on board the *Latouche-Tréville,* who was an eye-witness, is given in the "Temps":

"On Tuesday, 22d September, *tirs d'honneur* were being carried out from the *Latouche-Tréville* off Toulon, for the purpose of selecting the best shots from the men under instruction to receive certificates of captains of guns. The guns used were three 14-cm. (5.4-inch) and one of 19-cm. (7.6-inch) in the after turret, and it was in this latter that the explosion took place. The ship had been steaming along a firing base, and had arrived at the end of the run, and was turning 16 points to go back again, and bring the starboard guns into action. The 'Cease fire' was sounded, and as there would be a period of about three minutes before recommencing, advantage was taken of this delay to change the gun's crew; the gun, which was loaded, being left, in accordance with the instructions, with the breech unlocked. The officer in charge of the first gun's crew warned his relief that the gun was loaded, and after this no one can say exactly what happened;

but hardly had the new crew entered the turret—not yet quite evacuated by the old crew—when an appalling explosion took place, blowing the breech block of the gun through the door of the turret, and lifting off the roof shield, 95-mm. (3.6-inch) thick, which fell on the deck, killing one man, and then bounded overboard. A jet of flame also descended the ammunition hoist to the magazine, luckily without exploding the latter. The inside of the turret, in which every man was killed, presented a horrible sight. The marvellous escape of the two officers is due to the fact that they had just before moved out of the turret to give room for the new crew to pass in.

"It was at first thought that on account of the force of the explosion more than one charge must have ignited, but this was not the case, the other cartridges being found intact.

"One theory is that the new crew, on entering the turret, opened the breech, and that the draft of air into the gun caused gas left in the chamber by previous shots to ignite and fired the charge, while the breech block, not being closed, was naturally blown out. M. Thomson, Minister of Marine, on recéipt of the intelligence, at once proceeded to Toulon, and has been most unceasing in his attentions in visiting the wounded at the Saint-Mandrier Hospital, who he has decorated with the military medal. One of these two, unfortunately, did not live long to wear this distinction, and has since succumbed to his injuries, bringing the number of deaths up to 14."

The breech block, which was blown into the sea by the explosion, has since been recovered by the divers from a depth of 22 meters (72 feet), the percussion tube was found in place, and showed that it had been fired. This discovery would seem to put out of the question the theory of the explosion having been caused by a return flame, and the disaster would now appear to be due to neglect on the part of one of the gun's crew to remove the tube, according to the regulations, before opening the breech, and the tube was probably fired by tension of the tube lanyard (which may have caught in some way), caused by the withdrawing of the breech block.

The powder, which had been used up to the 47th round, came from the stock provided in 1899; but that in the gun at the time of the explosion was 1904-1906. A committee of enquiry is sitting, but the conclusions at which they have arrived have not yet been made known; one hypothesis is that the explosion was caused by some deleterious gases which had remained in the gun. Captain Darrieus, the commander of the ship, declares that he cannot accuse any of the gunners of carelessness, as, as far as was known, all the regulations laid down for firing had been most carefully carried out.—"Le Temps" and "La Vie Maritime."

THE FRENCH NAVAL SITUATION.

By M. Rousseau.

The principle on which the concentration of naval forces depends conflicts with that of the dispersal of squadrons in distant seas, which had prevailed up to 1904, and has ended naturally in the creation of a new class of ship equal to the world-wide rôle required of the modern vessel.

Generally speaking, naval officers look only at their ships from the fighting point of view, the advantages of different plans of armament, and the improvements to be introduced in these respects, a few only have considered the larger question as it affects their ship, and though admittedly she must be a fighting battleship, she must also possess all the attributes for arriving at the place of action at the desired moment, and in the best condition.

The concentration of the fleet in English waters, entailed, if not the complete abolition of the *points d'appui* in distant stations, at least a great reduction in their numbers, and in the importance of those still remaining, and the distance between these thus becoming greater, the necessity arose for increasing the speed and enlarging the radius of action of the ships, hence the introduction of the *Dreadnought* type of battleship with a nominal displacement of 17,000 tons, but a real displacement

of more than 19,000 tons, on account of the supplementary supply of fuel that can be carried. Large as it is, this displacement is now exceeded, our battleships of the *Danton* class are larger, and the displacement of our projected battleships is 21,000 tons. In England each new ship built is larger than her predecessor; the American battleship, whose design has been submitted to Congress, will displace 22,000 tons, and M. Laubeuf predicts the advent of vessels of 25,000 tons.

As has been said, the new ships of the *Dreadnought* era are necessitated by the ever-increasing demands of the new strategy. In Lord Cawdor's report of November, 1905, we read the Admiralty view on the importance of rapid construction: "The quicker a new vessel can be put through her trials, the easier is it to introduce improvements which experience has shown to be necessary in succeeding vessels of her class, consequently it is most desirable to finish off the first vessel of a batch as soon as possible." This makes it clear that in constructing the *Dreadnought* the British Admiralty was taking a leap in the dark, and the experiments conducted with this ship show that besides her machinery trials her rôle and efficiency, from a strategical point of view, were also fully considered, and the necessity is also affirmed of constructing new ships in series.

This necessity is greater with the ship of the new era than with her predecessors, for if we consider that they are intended to act at great distances from their base, it is obvious that the naval force of which they form a part must be absolutely homogeneous to give the best results; difficulties might be doubled, and operations might even become impossible were there too great a difference among the ships. All must have the same speed, for the slowest ship regulates the rate of progress of the fleet; they must have the same radius of action, for the distance that can be traversed is limited to the means of the ship carrying the smallest supply or consuming the largest amount of fuel; the guns must also be disposed in a like manner on all the ships, for the fire effect will be greater if a larger number of guns can be converged on the object, and the ships must be protected to the same degree, the thickness of the armor deter-

mining the fighting range at which they will be more or less invulnerable without compromising the full effect of their own guns.

The homogeneity of a naval force depend upon all of these questions and though it need not concern itself with turbine or piston engines, with B-powder or cordite, or with horizontal or vertical-tube boilers, it is evident that the necessities of modern warfare oblige us to push this matter of homogeneity as far as we can; not only are ships of the same military power demanded, but also with the same means of producing this power, for there is besides battle-homogeneity also mobilization-homogeneity.

If the predominant idea in the conception of the *Dreadnought* is that of, so to speak, producing an autonomous vessel, able to act without reference to *points d'appui* and their resources for supplies and repair, the immediate consequence of the autonomous fleet is the organization of a floating service for repairs and replenishing of stores. This floating service, now termed *train d'escadre,* is a group of auxiliary vessels able to supply the current needs of a fleet and execute all repairs due to damage in action, or at least those that can be carried out without going into dock. It is with this object that the British Admiralty has constructed the *Assistance,* the *Aquarius,* and other vessels, whose names symbolize their duties. It is clear that the *train d'escadre* will be all the more efficacious the less varied or numerous the needs to be supplied. If all the men in an army had the same sized heads, the same clothes and foot measures, the clothing of them at mobilization would be much simplified; every man cannot be made alike, but there is no reason why ships should not be similar. If all the boilers in a fleet are of the same pattern, the repair ships will only have to carry one kind of a boiler tube, and if the caliber of the guns is the same, they will have to carry but one nature of projectile; in thus unifying the different elements in the ships, the supplies and material to be carried by the *train d'escadre* is much simplified, and the chances of mistake reduced to a minimum. It

may be mentioned that England has put the same nature of boilers in her three latest *Dreadnoughts,* not because of the superiority of this type, but because the *Dreadnought* herself carries them.

Some people affirm that the adoption of a single caliber of heavy gun is the result of the lessons of the battle of Tsushima; this, however, is not borne out by the fact that both the belligerents, Russians and Japanese, have armed their most recent ships with different descriptions of guns, and that they have not discarded guns of a medium caliber. The unification of caliber is necessitated more by questions of mobiliza tion than by battle conditions.

Moreover, the *Dreadnought* was designed long before the battle of Tsushima, preceding even the commencement of the Russo-Japanese War. In the August, 1903, number of the "Navy League Journal," a new type, an improved *King Edward* of 18,000 tons, was proposed. The *Dreadnought* is par excellence the type of vessel that conforms with the new distribution of the fleet, and synchronizes most with the modern formula, "concentration of power and transportability of effort."

English genius has solved the application of this formula, but will the solution be to the profit of that country? Was it wise of the British Navy, with its many coaling stations and arsenals in all quarters of the globe, to show that it is possible to do without such *points d'appui?* There can be no doubt but that it is this demonstration which is the cause of all other navies now adopting this new class of ship. The Germans have increased the displacement of their new battleships by nearly 50 per cent., namely, from 13,000 to 19,000 tons. The English have taught the Germans that the world power of a fleet may reside in itself, and need not depend on territorial possessions along the ocean highways.

Germany perceived that with the *Dreadnought* type the field of action of her fleet might be unlimited, and though previously she had no necessity for ships of large tonnage, she has now

modified her naval program, and is constructing a number of these monster vessels.

It need hardly be said that the displacement of armored cruisers has increased in the same proportion as the battleships, and there is now little difference between the tonnage of the two classes. Properly speaking, the armored cruiser no longer exists—there is "the line" of battleship and the cruising battleship, the former is slower, but both have powerful armaments, and their armored protection is nearly the same. The latest English battleship will carry ten 305-mm. (12-inch) guns and twenty 101-mm. (4-inch) guns, the latest armored cruisers carry eight 305-mm. (12-inch) and sixteen 101-mm. (4-inch) guns, but the former have a speed of 21 and the latter of 25 knots. The principle of homogeneity has made it necessary to place identical guns on board new ships of different classes, the difference between the two types is one only of the number of different fighting elements.

To resume, it may be said that the characteristics of the modern navy—of a squadron of *Dreadnoughts*—are augmentation of displacement to increase speed and radius of action, and reduction in the number of fighting elements to simplify the replenishing of stores and fuel, and the carrying out of repairs. The motto of the new navy is: "Strength with simplicity.

The evolution of the *Dreadnought* type of battleship still goes on, each Navy endeavoring to produce something better. It is the combination of different qualities which conduce to the superiority of this class of ship. If she be considered simply as a fighting unit, this superiority is not so evident, for it is easy to conceive a vessel of less tonnage able to throw a greater weight of projectiles; but in such a case it would be necessary to sacrifice speed and radius of action, just as in the new cruiser battleship it has become necessary to reduce the protection and the size of the guns to obtain a speed of 25 knots.

If we admit this, it may be asked: Why have all nations

without hesitation adopted these very large displacements? Their adhesion to the principle of the giant battleship shows in the clearest manner that no Admiralty has confidence in a purely defensive navy. The attack on Port Arthur convinced everyone that rapidity of movement and quickness of action is the chief factor in success; and the *Dreadnought* is essentially offensive on account of her speed, and because she is autonomous. The tests through which she has been put after her first trials have amply affirmed this quality. She made a non-stop passage from Gibraltar to the West Indies, and on her arrival on the American side still had enough fuel in her bunkers to allow of her steaming 1,000 miles farther, notwithstanding that her speed had much exceeded the economical limit.

The example set by England has been followed by practically every nation, and now only *Dreadnoughts* are being constructed. In England the situation is as follows: The *Dreadnought,* completed more than a year ago, flies the flag of Vice Admiral Bridgeman, Commander of the Home Fleet; three other battleships (*Bellerophon, Superb* and *Temeraire*) of 18,000 tons were launched in 1907, and will be ready at the end of the current year; three more (*St. Vincent, Collingwood* and *Vanguard*) have just been laid down, and have a displacement of 19,250 tons, and will be completed at the end of 1909 or commencement of 1910; finally one other battleship is to be commenced in the financial year 1908-1909 and finished two years later. Of cruiser battleships, three (*Inflexible, Invincible* and *Indomitable*) are afloat, and will shortly be completed; and another of this class of the same displacement—17,250 tons—will be commenced during the present financial year.

Thus, at the end of 1908 England will possess eleven armored vessels of the *Dreadnought* era, either in commission or completing. This number does not seem so important when we remember that these eleven ships represent a four years' program of new construction, and if we recall that quite re-

cently Mr. Asquith, in the House of Commons, and Lord Tweedmouth, in the House of Lords, said that the rule of the two-Power standard would continue to be the guide of the Admiralty. We must nevertheless admit that, thanks to the advantage gained by being before other Powers, the British Navy is certainly superior at present to the combination of any other two; but if the new type of vessel has considerably lessened the value of preceding types, it is to be feared that in the near future a combination of two fleets may arise superior to that of England.

But, besides the two-Power rule, the British Admiralty has laid down, according to Lord Cawdor's memorandum, that the "demands of strategy necessitate the production of four large ships per year, and unless unforeseen contingencies arise, this number should not be exceeded. The period of construction of a battleship is two years, and as four ships will be laid down each year, in any single year there will be eight vessels of this class under construction, either in the dockyards or private yards."

By 1905 it had become difficult to distinguish between the battleship and the armored cruiser—both were classed under the general description of large armored vessel. Speaking of the intention to construct four battleships per year, Lord Cawdor laid this down as the future Admiralty program, and as, according to the English estimate, the life of a battleship may be put at 25 years, it follows that the British Admiralty aim at having an effective force of 100 battleships. This may also be inferred from Appendix VII, of the Naval Estimates, which allows for an annual depreciation of 40 per cent. per ship, this being also the basis of calculation for the estimated sum necessary for their replacement. (A paper distributed to the British Parliament in July gives the effective number of battleships in the fleet as 65, of which 5 are under construction, and the number of armored cruisers as 38, of which 8 are under construction.) Besides the two-Power standard the Admiralty has, therefore, another guide to work by; but it

must be stated, notwithstanding, that the "Navy League Journal" for March shows, as regards the Cawdor program, that there has since been a falling off of 25 per cent., and that in four years the number of ships laid down will be only 12 instead of 16 required.

If building activity in the British Navy appears to have slackened, this is not the case in the German Navy, whose program, which dates from 1898, is being continually modified in an increasing sense. The latest change—and, perhaps, the most important—is the one which has received least attention. The life of a battleship, which had been fixed at 25 years, has been shortened to 20 years, which means that Germany to replace her worn-out battleships will construct five new ships instead of four. If England is losing 25 per cent. per year on her program, Germany, on the contrary, is gaining that amount, and in 1908, 1909 and 1910 she will lay down four *Dreadnoughts* every year.

The adoption of these large ships has caused a certain amount of perturbation in the German Navy, and the regular sequence of her building program has suffered in consequence; but the time lost has now been pulled up, and at the end of 1908 Germany will have 9 of these giant ships building or afloat, and one year later she will have 13, which means that if England does not make a further effort she will possess no advantage at the end of 1909 over her competitor.

The following are the details as regards the German *Dreadnoughts:* Two first-class battleships of 17,710 tons were commenced in August, 1907, the first of which, the *Nassau,* has just been launched. Two of 19,000 tons and one cruiser of 18,900 tons were commenced in November, 1907, and during the current year three battleships of 19,000 tons and a cruiser of 18,900 tons will be commenced. The period of construction of each of these vessels is fixed at eighteen months.

The situation in France is quite simple. Six battleships of 18,350 tons were laid down in the end of 1906; they will be completed in 1910 or the commencement of 1911; no others

are to be commenced this year, but it is understood that six new battleships will be commenced in 1909 and 1910.

The American Navy has only two battleships of 20,000 tons actually building—the *New York* and *Delaware*. What further vessels will be laid down depends on the vote of Congress. The Government proposed to commence four battleships of 22,000 to 25,000 tons, but it would appear that Congress is not disposed to vote for more than two.

The building program of Japan may be compared to that of England. In the first quarter of 1905—that is to say, during the war—two battleships, the *Satsuma* (19,250 tons) and *Aki* (19,780), were laid down, and are both now launched. Towards the end of 1907 plans were drawn for two more battleships of 22,000 tons and one cruiser of 18,650 tons, and it is proposed to lay down one battleship of 22,000 tons and two cruisers of 18,650 tons this year.

There remains Russia, but in the present state of politics in that country it is not possible to say accurately what additions will be made to her fleet.

To resume, at the end of 1908 there will be built the following battleships of the *Dreadnought* era:

	England.	Germany.	United States.	France.	Japan.	Total.
Battleships....	8	7	4	6	5	30
Cruisers....	4	2	0	0	3	9
	12	9	4	6	8	39

—a total of 39 vessels, of which 20—or more than half—are possessed by England and Japan, whose alliance binds them to act together in case of a combination of the other Powers. On the other hand, England by herself would be outnumbered by any combination except that of France with the United States, though as regards the latter the number of her large battleships is not yet definitely fixed.

I have already said that Navies can best be compared by the number and fighting value of battleships possessed, as a

maritime war must be decided by great naval battles; and the only vessel to act in the fighting line is the first-class battleship. But though the battleship is the fighting ship *par excellence*, it does not follow that there is no need for auxiliary vessels. Admiral Fournier wished for a fleet composed only of armored cruisers, but fit to do anything; fight, scout, protect or destroy commerce; but it was pointed out at the time that an armored cruiser can not be expected to stand up to a battleship, and that if used as a scout the cruiser locked up too large a crew and burnt too much fuel; while, as regards commerce protection, so large a number would be required that the price of protection might exceed the value of commerce to be protected. Admiral Fournier did not come out of the region of theory, and France has continued to build vessels of different types, about which it is necessary to say something.

If all are in agreement as to the points of a good battleship, there is not the same unanimity of opinion regarding the subsidiary vessels of a fleet. Scouts are allowed to be necessary, but what kind of scout, and in what proportion? In France we are not building any scouts, and the intention is to use destroyers of 330 tons for the purpose; but in anything like bad weather this would lead to the battleships scouting for the destroyers. In England they seem to have arrived at some conclusion, and in 1903, 1904 and 1905 a class of scouts of 2,800 tons to 3,000 tons were built. It was intended to regularly attach them to the different fleets, but they still remain at the different naval ports, apparently not approved of even before they have had a fair trial. Last year a protected cruiser of 3,300 tons was laid down, and she is to have the same speed as the scouts, and this year five protected cruisers of 4,000 tons to 5,000 tons are being commenced. One vessel also, of 1,800 tons and 30 knots speed, is being built, designated, according to the Estimates, a torpedo vessel. For what purpose is she intended? Her utility is not clear. What, however, is certain is that she will be more or less of a luxury, and that any large number of this class could not be built.

The United States have also built scouts of 4,000 tons dis-

placement and 24 knots speed, which are now going through their trials. In Japan the same hesitation reigns as in England. In 1907 they launched a cruiser of 4,000 tons and 25 knots; one of 1,250 tons and 22 knots; and one of 1,350 tons and 25 knots. I am not in their secrets, but this appears rather unsystematic. Germany alone is methodically pursuing the construction of small cruisers, and has as many of them as battleships. No one knows for what purpose, but it is evident that if the German Admiralty builds so many they have their own reasons. They commenced with 2,645 tons displacement and 20 knots speed, and have raised this to 3,800 tons and 25 knots speed. The new English cruisers would appear to be a reply to the German ones.

The search for the best type of fighting ship leads inevitably to an increase of tonnage, for up to the present all progress tends in the direction of increased weight of engines. It may also be noted as peculiar that the Peace Conference has proved to be a fresh starting point for increased activity in war-ship building and further development in the arms with which they are provided.—"Le Temps–Journal Royal Service Inst."

ENGINEER OFFICERS IN THE GERMAN NAVY.

An Imperial Order has been issued giving engineer officers in the Navy the same rank and precedence as officers of the executive branch, and to mark the change in their position these officers are for the future to wear the same swords as those of the last named.

German public opinion has recently shown some concern at the number of mishaps to ships of the fleet (the grounding of the *Scharnhorst,* the *Hessen, Kaiser Wilhelm der Grosse,* etc.), which have come to light, and certain journals have gone so far as to ask whether Prince Henry is not too often absorbed by the exigencies of his high position to be able to devote himself as much as he should to his duties as Commander-in-Chief of the High-Sea Fleet.

Some surprise has been expressed at the recent apparent supersession of Vice Admiral Wodrig in the appointment of Director of Dockyards at the Ministry of Marine, especially in view of the fact that he seemed peculiarly well fitted for the post, as he has previously for some years been superintendent of the dockyard at Wilhelmshaven. He has been succeeded by Vice-Admiral Breusing, who was his successor at Wilhelmshaven. The Dockyard Department at the Ministry of Marine is responsible, among other duties, for the armament, equipment and maintenance of the fleet. The Department is divided into nine sections:

a Administration of the dockyards, under a captain.
b Service of automobile torpedoes, under a commander.
c Service of mines and booms, under a captain.
d Personnel of the dockyards, under a captain.
e Armament and fitting out of ships, under a captain.
f Repairs of ships, under an engineer of naval construction.
g Repairs of machinery, under an engineer of naval construction.
h Hydraulic works, under an engineer.
i Torpedo-boats (new construction), under a civil official.

—"Journal Royal United Service Inst."

STEAM TRIALS.

The new first-class battleship *Schlesien* has been going through her trials successfully. During a 24-hours' run with the engines developing 3,574 I.H.P., the mean speed was 12.2 knots, with a coal consumption of 886 gr. ($1\frac{7}{8}$ pounds) per I.H.P. per hour. During a three-hours' full-speed trial the engines developed 20,507 I.H.P., making 121.2 revolutions, and giving a speed of 19.53 knots.

A noticeable fact in connection with the speed trials of German battleships has been the steadily increasing rate of speed obtained. The four vessels of the *Brandenburg* class, with a displacement of 10,300 tons, which were laid down in the year

1890, had a speed of 16 knots. They were followed by the five ships of the *Kaiser* class, of 11,130 tons displacement, laid down between the years 1896-98, in which the speed was increased to 17.5 knots. In 1899-1900 came another group of five ships, the *Wittelsbachs,* the displacement of which was not much greater than the *Kaisers,* in which the speed was raised to 18 knots. In 1901-02 followed the group of five *Braunschweigs,* in which the displacement went up to 13,200 tons, with a speed of between 18.5 and 18.7 knots. Then in 1903-05 came the five ships of the *Deutschland* class, the last ship of which, the *Schleswig-Holstein,* has recently completed her trials. As originally designed the speed of the *Braunschweig* and *Deutschland* classes was also fixed at 18 knots; but, as we have stated, all five of the first-named type exceeded this speed by a good half knot, and the *Deutschland* also made 18.5 knots on her trials. In response, however, to pressure from the naval authorities the makers of the engines and boilers of the four remaining ships have succeeded in still further increasing the speed, the *Hannover, Schlesien* and *Pommern* having all made slightly over 19 knots, while the last of the group, the *Schleswig-Holstein,* in her full-speed trial over the measured mile in deep water, averaged the high speed of 19.5 knots. As the designed speed of the first four of the new German *Dreadnoughts* is only 19 knots, for fleet purposes the *Deutschlands* can be well combined with them to form one squadron if necessary.—"Jour. Royal United Service Inst."

NEW GERMAN SHIPS.

The new first-class battleship Ersatz *Sachsen* was launched on the 1st of July from the Weser yard at Bremen, and received the name of *Westphalen;* she is the second of the German *Dreadnoughts* to take the water. According to the "Hambourger Nachrichten" her dimensions are as follows: Length, 472 feet; beam, 83 feet; draught, 26 feet 4 inches, with a displacement of 18,000 tons. The engines are to develop 24.-

000 I.H.P., giving a speed of 19 knots, and she will have a radius of action of 5,500 miles at 10 knots. Protection will be afforded by a 12-inch belt, tapering to 4 inches at the extremities, with 11-inch armor for turrets and casemates, and 12-inch for the conning tower. The armament is to consist of twelve 50-caliber 11-inch guns and twelve 6-inch guns, with six submerged torpedo tubes.

Of the three new battleships of this year's program, the Ersatz *Oldenburg* is to be built at the Imperial dockyard, Wilhelmshaven, the Ersatz *Beowulf* at the Weser yard, Bremen, the Ersatz *Siegfried* at the Howaldts yard, Kiel, the large armored cruiser *"G"* at the yard of Blohm & Voss, of Hamburg, a firm which has already built the armored cruisers *Friedrich Karl, Yorck* and *Scharnhorst,* and has under construction at the present time the new armored cruiser *"F,"* of last year's program. The small cruiser Ersatz *Sperber,* at the Imperial Dockyard, Kiel, and the small cruiser Ersatz *Schwalbe,* at the Germania yard, Kiel. Of the twelve destroyers, three are to be built at the Vulcan yard, four at the Schichau-Elbing yard, and five at the Germania yard, Kiel. They are all to be of 616 tons and to be fitted with turbine engines.

A delay, due presumably to the labor troubles, has arisen in the launching of the Ersatz *Württemberg,* building in the Vulcan yard, Stettin, which was to have taken place on the 22d ultimo, and no intimation has yet been given as to the date when she now may be expected to leave the slip; she will be the third of the new 18,000-ton battleships to take the water. Although the contracts for all the new armored ships of this year's program have been given out, it does not appear that an actual commencement has yet been made with any of them, and it is stated that delay has arisen from the plans not having yet been finally settled, owing to the authorities not having come to a decision on the vexed question of the armament. It is stated that Krupp has been experimenting for some time with a view of the construction of 12-inch or even 13.5-inch guns, but it seems certain that the great bulk of naval expert

gunnery opinion is against the mounting of any heavier ordnance in the new ships than the 11-inch gun, and even that gun is looked upon by many officers as needlessly heavy.—"Revue Maritime, Marine Rundschau," and "Neue Preussiche Kreuz Zeitung."

THE PERSONNEL OF THE GERMAN FLEET.

The Officers' Corps.—The following are the numbers of the officers of different ranks on the Active List of the Fleet: 4 Admirals, 7 Vice Admirals, 16 Rear Admirals, 75 Captains, 178 Frigate and Corvette Captains, 403 Captain-Lieutenants, 952 Lieutenants, 398 Midshipmen and 185 Naval Cadets.

There are, further, 1 retired Rear Admiral, 10 retired Captains, 22 retired Frigate and Corvette Captains, and 6 retired Captain-Lieutenants employed on special duties, while 49 Captain-Lieutenants and 87 Lieutenants are employed in ordnance and torpedo duties in the various dockyards and coast stations.

The staff of the Marine battalions is as follows: 1 Colonel (Inspector of Marine Infantry, with the rank of Regimental Commander), 2 Battalion Commanders, 13 Captains, 14 First Lieutenants, and 22 Lieutenants. The Marine Field Artillery has 4 Captains, 1 First Lieutenant, and 6 Lieutenants, and the Engineer and Pioneer detachment 3 Majors, 1 Captain, and 1 First Lieutenant.

The Engineering Department consists of 10 Chief Engineers and Senior Staff Engineers, 57 Staff Engineers, 101 Senior Engineers, and 162 Engineers, being an increase of 35 over the number of last year.

The Medical Director-General consists of 1 Medical Director-General (with the rank of Rear Admiral), 4 Inspectors-General, 54 Fleet Surgeons, 85 Staff Surgeons, 51 Surgeons. and 52 Assistant Surgeons, an increase of 13 over last year.

In the Accountant Department are 37 Staff Paymasters and 166 Senior Paymasters and Paymasters.

Seamen, Stokers, etc.—The Seamen's Divisions number 140

Chief Warrant Officers, 209 Warrant Officers, and 18,557 Petty Officers and Seamen, with 96 Boys' Instructors and 1,554 Boys, a total of 20,556, showing an increase of 18 Chief Warrant Officers, 10 Warrant Officers, 1,331 Petty Officers and Seamen, and 150 Boys.

The Dockyard Divisions number 347 Chief Warrant Officers, 694 Warrant Officers, and 13,249 Petty Officers and men, of whom 930 Chief and Warrant Officers and 10,849 Petty Officers and men form the engine-room personnel of the Fleet, which shows an increase of 48 Chief and Warrant Officers, and 714 Petty Officers and men over last year, with a total increase in the divisions of 53 Chief and Warrant Officers, and 821 Petty Officers and men.

The Torpedo Divisions number 106 Chief Warrant Officers, 213 Warrant Officers, and 5,796 Petty Officers and men, of whom 60 Chief and Warrant Officers, and 2,617 Petty Officers and seamen are of the seamen class, while 259 Chief and Warrant Officers, and 3,179 Petty Officers and men are of the engineering branch. There is an increase in the divisions of 17 Chief and Warrant Officers and 362 Petty Officers and men of the engineering branch and of 4 Chief and Warrant Officers and 217 Petty Officers and men of the seamen branch, a total increase in both branches of 21 Chief and Warrant Officers, and 579 Petty Officers and men.

The Seamen Artillery Division and Mining Detachment numbers 25 Chief Warrant Officers, 49 Warrant Officers and 3,373 Petty Officers and men, of whom 12 Chief Warrant Officers, 23 Warrant Officers, and 677 Petty Officers and men belong to the Mines Division. There is an increase of 1 Chief Warrant Officer, 4 Warrant Officers, and 177 Petty Officers and men over last year, of which increase 1 Chief Warrant Officer, 2 Warrant Officers, and 64 Petty Officers and men are in the staff of the mine detachment.

The Marine Infantry numbers 210 non-commissioned officers and 1,153 men, an increase of 19 non-commissioned officers and 115 men.

The Sick-Bay Staff consists of 506 Petty Officers and men of various grades, being an increase of 34 over last year; and there are 346 ships' stewards, writers, and assistants.

The sum total of all ranks is 50,323, being an increase of 3,576 as compared with 1907.

Personnel.	Officers.	Doctors.	Non-commissioned officers and seamen.				Total all ranks, 1908.	Increase compared with 1907.
			Warrant officers.	Petty officers.	Seamen.	Boys.		
Naval officers	1,678	...	...	...	...	...	1,678	91
Junior executive officers	...	...	...	398	185	...	583	30
Engineer officers	330	...	...	...	...	...	330	35
Seamen, boys, dockyard and torpedo divisions	...	...	1,709	8,582	29,020	1,650	40,961	3,043
Seamen artillery	...	...	74	454	2,919	...	3,447	182
Marine infantry	52	...	...	210	1,153	...	1,415	136
Personnel of the clothing department	...	...	...	27	150	...	177	48
Medical department	...	247	...	214	292	...	753	47
Artillery administration	83	...	109	63	...	...	255	14
Torpedo personnel (technical and adm'strative)	53	...	119	49	...	...	221	12
Mining personnel (technical and adm'strative)	25	...	40	64	...	...	129	17
Accountant department	...	...	83	214	49	...	346	17
Surveying department	...	...	28	...	...	...	28	...
Total	2,221	247	2,162	10,275	33,768	1,650	50,323	3,576
	2,468		47,855					

—"Etat für die Verwaltung der Kaiserlichen Marine auf das Rechnungsjahr," 1908.

RECENT ADVANCES IN STEAM TURBINES.

The progress of the steam turbine is to be seen in all directions, and one thing which is especially remarkable is the rapid increase in size. Eight years ago the largest one made, which was considered an immense machine at the time, was for only 1,000 kw., and now there are large numbers ranging from 5,000 to 8,000 kw. running and under construction.

Steam turbines of large size may be roughly divided into two classes, comprising, firstly, the Parsons turbine, in which there

is both action and reaction, and the expansion takes place equally in the moving and fixed blades; secondly, those in which the whole of the expansion takes place in the fixed blades, the velocity of the steam being taken up without expansion by the moving blades. This latter class can then be subdivided into those in which at each stage there is only a single row of moving blades as in the Rateau and Zoelly turbines, or one in which there are several rows of moving and fixed blades in each stage, which take up the velocity without any additional expansion, as in the Curtis. There are again various combinations, consisting of mixtures of one or more classes, but none of these have, as yet, been manufactured to any large extent. The oldest type, and one which is more in use than any other, is the Parsons, but in America the Curtis has been manufactured in large numbers, and on the Continent the Zoelly, Rateau, and A.E.G., although both in America and on the Continent the Parsons has taken a leading position.

The Turbo Dynamo.—Hand in hand with the development of the steam turbine has gone the development of the various machinery to be driven by it, and in this direction electrical machinery has been prominent. For many years continuous-current turbo dynamos were looked at askance by engineers on account of commutation troubles, for it is easy to see that the ordinary constants applicable to slow-speed dynamos to secure sparkless commutation are far exceeded when the speed is raised to that of turbine-driven dynamos. On this account it was early seen that some sort of compensating winding to improve the commutation and compensate for the reaction of the armature was necessary. Commutating poles alone have not proved satisfactory in practice, there being nearly always considerable difficulty in securing good commutation with them, and as a consequence commutating poles combined with compensating windings—the commutating poles giving the reactance voltage necessary for commutation and the compensating winding, compensating for armature reaction—have been

adopted by many firms. But even better commutation can be secured by a compensating winding alone, in which the ampère-turns of the compensating winding exceed the ampère-turns of the armature to such an extent as to give a commutating field in the gap between the pole-pieces.

Such compensating winding is generally chiefly concentrated on the pole-pieces, and is made with from 2 to 2½ times the number of ampère-turns of the armature, in order both to compensate for leakage and to give a good commutating field; and since this method of compensating has no iron commutating pole, it has the advantage that there is no self-induction to cause time lag at sudden changes of load, and, as the field of the gap between the poles is entirely in air, it instantly responds to changes of current in the compensating winding, and thus the sparking found when there is a sudden change of load with commutating poles is avoided, and the risk of a flash-over largely reduced.

Also, since there is no iron to become saturated, the commutating field is always strictly proportional to the load, and thus the trouble due to saturation causing sparking at some loads and not at others is avoided. This advantage is specially prominent where the dynamo is required to give varying voltages and to commutate at any of them without outside adjustment of the compensating windings by diverters or otherwise.

The adoption of these devices has made it possible to make turbo dynamos of large size, and now as much as 1,500 kw. is put into a single armature, whereas before such compensating devices were adopted 500 kw. was the maximum, and even then the commutation was anything but satisfactory.

Standard Pattern.—In turbo alternators there is practically now—except for small sizes and low voltages—one standard pattern—that is, a revolving field rotating inside a stator. In the stator there is little variation in design, except in regard to the ventilating arrangements, which have to be very ample on account of the comparatively large quantity of heat to be removed from a small volume.

One point which has received great attention in recent years is the staying of the end windings of such alternators, it having been found that, owing to their great length, when a "short" took place the stresses on the winding were such as to break the insulation and cause disaster. The amount of these forces has been vastly more than was ever anticipated, and if the windings are not thoroughly stayed, such movements may be set up as to cause disaster. In the rotors there are two prominent types, the barrel and the salient pole, and much discussion has ensued as to the advantages of the one or the other. After considerable experience of both, on the whole I may say that at present I prefer the salient pole type. Ample ventilation is much easier to provide for, and improvements made in protecting and supporting the field coils of this type of rotor have resulted in a design giving great reliability with the maximum use of the space available. One improvement has been enclosing every coil in a tight sheath of sheet steel, so that any movement which may take place due to centrifugal force is between the steel sheath and the body of the rotor, and thus the insulation is protected from any rubbing which might cause it to be cut through and, consequently, break down.

Voltage regulation of alternators is also of considerable importance, as owing to the inductive load required by induction motors there is a heavy demagnetizing effect on the rotor, and consequent drop of voltage when the load rises. Several methods have been proposed for compounding alternators, most of them requiring a separate commutator or moving contacts altering the resistance of the exciter or main windings, but a method of compounding alternators has recently been brought out, which is being largely used with good results. In this apparatus the current supplied by the machine is made to act on the exciter field system in such a way as to reduce the leakage, artificially increased in the first instance, and so raise the voltage of the exciter, and increase the excitation of the alternator, so that any desired amount of compounding required can be obtained. This arrangement has been recently

described in a paper before the Institution of Electrical Engineers.

Turbo Blowers.—The other applications of the steam turbine, such as driving air compressors and pumping water, have also been largely extended during the last few years, and especially prominent in this direction has been the application of turbo blowers to blast furnace work, some having been recently installed for as much as 50,000 cubic feet of air per minute at 10 to 15 pounds pressure. In this connection it may be mentioned that a very usual size, which is for about 20,000 cubic feet, weighs about 25 tons, and that an ordinary reciprocating blower of equal capacity weighs about 450 tons or about eighteen times as much as the turbo blower.

In many parts of the country reciprocating engines are running non-condensing, and it has now been found that the exhaust steam from them is of great value. Such exhaust steam cannot be practically utilized by reciprocating engines on account of the huge size and volume of the cylinders required, but it is quite otherwise with the steam turbine, where the large volumes of the low-pressure steam are exactly what are required for the highest economy. These considerations have led to the introduction of exhaust steam turbines, taking steam at atmospheric pressure and exhausting into a condenser.

When it is remembered that there is as much power in the steam from atmospheric pressure down to 27½ inches as there is from 150 pounds down to atmospheric pressure, it is easily seen that the power of a non-condensing plant can be doubled by the addition of an exhaust steam turbine and condenser, and in cases where there is not a supply of cooling water, improvements in cooling towers have enabled them to be put up both cheaply and well.

In this connection the use of intermittent supplies of exhaust steam, such as that obtained from engines running intermittently, as in rolling mills or winding engines at collieries, has received a great impetus by the utilization of thermal accumulators, in which the intermittent supply of steam is alternately

condensed and re-evaporated, so that a constant flow is obtained for use in the exhaust steam turbine.

And yet another refinement has been introduced by the use of mixed pressure turbines, in which there is a low-pressure part sufficiently large to give full power when working with exhaust steam, and if the supply of this fails, a high-pressure part is brought automatically into action, using steam direct from the boilers, and thus there is economical running, whether the reciprocating engines supplying the exhaust steam are working or not.

The Question of Vacuum.—In all turbines the question of vacuum is a very important one, and various improvements have been made in condensers to enable higher vacua to be obtained. The importance of this will be seen when it is remembered that in the average steam turbine, 1 inch of vacuum is equivalent to from 4 to 5 per cent. of steam consumption, or, in other words, it may be taken that for every 3° F. by which the temperature due to the vacuum is reduced, a gain of steam consumption of 1 per cent. is made.

In this connection increase of circulating water is very important. A very usual amount is about thirty times, but if this is increased to 45, the gain in consumption is 4 per cent., and if increased to 65 times a further gain of 2 per cent. is made. As a rule, extra circulating water can be pumped without much difficulty, the extra power required for this being very small, but generally the temperature of the inlet to the condenser is fixed by the supply of water available.

The great desirability, then, in a condenser is to obtain the temperature due to the vacuum as close as possible to that of the water leaving the condenser, as, of course, the maximum vacuum possible is that due to the temperature of this water. In ordinary condensers, it is generally found that this difference amounts to 20 to 25° F., and among the various arrangements to reduce this may be mentioned dry-air pumps, and also the arrangement of baffles and pumps in the "contraflo" condenser. But a method which has been very satisfactory in

practice is what is called a "vacuum augmentor," which is simply a small jet of steam drawing the air and vapor from the condenser, and delivering it through a small auxiliary condenser to an ordinary air pump, so that while there may be, say, a vacuum of only 27½ inches at the air pump, 28½ inches or 29 inches may be attained in the main condenser. Such an appliance is especially valuable when, as is often the case on board ships at sea, the system has considerable air leaks. With this arrangement the difference between the temperature of the water leaving the condenser and that due to the vacuum can be reduced to about 5 or 6° F., and this when condensing up to 12 pounds of steam per hour per square foot of condenser. As will be seen, this shows an economy in the turbine of some 6 per cent. in steam consumption above an ordinary condenser, and when it is remembered that the steam jet of the augmentor uses only about 0.6 of 1 per cent., or only one-tenth of the steam consumption gained, it is easy to see that a great benefit is derived from the use of such an arrangement.

Marine Turbines.—In marine work the development of the steam turbine also is very rapid. Two years ago the great express Cunarders *Lusitania* and *Mauretania* were only in process of construction, now they have proved themselves to be the fastest liners afloat, and it is pleasing to note that the turbines of these great ships have proved most satisfactory on service. It was a great step from the 8,000 H.P. of a cross-channel steamer, which was the largest that had been made at the time these boats were designed, to the 65,000 H.P. of these express Cunarders, and reflects great credit on the courage and foresight of the Cunard Co., and also on the various contractors, designers and engineers engaged, that they have made such a great step in advance without, as many people prophesied, building another couple of *Great Easterns*. More mistakes have been made in going from a small to a large thing in engineering than in anything else, but the various pitfalls which awaited those responsible have been successfully avoided.

It is also interesting to note that the turbines proved themselves to be very economical, a consumption of 12.77 pounds per shaft horsepower having been attained as an average of the whole voyage across the Atlantic with about 150 pounds pressure at the entrance of the turbine, and a vacuum of 28.3 inches, barometer 30 inches.

At present all cross-channel steamers in hand are being fitted with steam turbines; the whole of the ships in the Admiralty program have also turbine engines, and everyone knows what a success the *Dreadnought* and the *Indomitable* are, they being respectively the fastest and most powerful battleship and cruiser afloat.

Hitherto, the link supplied between the steam consumption in a marine engine, and the horsepower developed, which is represented by the indicated horsepower, has been missing in a turbine, but the introduction of the torsion meter, which measures the horsepower passing through a shaft by the amount of torsion caused, has supplied this missing link most satisfactorily. The introduction of this has been chiefly due in this country to the enterprise of Messrs. William Denny & Bros., of Dumbarton, and on the Continent to Mr. Frahm, of Messrs. Blohm & Voss, of Hamburg, both of whom on slightly different lines have worked out torsion meters which have proved very satisfactory in practice. This has enabled the various losses between the power in the steam and the power required to propel the ship to be even better located than they are in the case of a reciprocating engine where the indicated horsepower does not take into account the friction of the engine.

Mixed Pressure Turbines.—The steam turbine, up to the present, has been almost entirely used for ships of 17 and 18 knots and above, and, in fact, it may be generally said that about 15 knots is the lowest speed of vessel at which the turbine can satisfactorily compete with the reciprocating engine as regards economy. The difficulty of the problem lies in the

fact that at low speeds the screws have to be made to revolve at small revolutions, and at the same time the horsepower required is moderate, and thus the turbines have to be very large and heavy, and, besides this, the blades are so short that the loss by leakage is excessive. These considerations have led to the combination of a reciprocating engine for the high-pressure part of the range where the volume of steam is small, and where the reciprocating engine is working exactly under the conditions for the best economy, and a turbine for the low-pressure part of the range where the volume of steam is large, and where, therefore, the turbine is working under the very best conditions, and such an arrangement gives advantages over either the turbine, or the reciprocating engine for moderate speeds, and, in fact, it is anticipated that an extra economy of about 15 per cent. can be attained in this way. The advantages of such an arrangement were first pointed out by Mr. Parsons in 1894, but has only recently been put into practice. Many various arrangements and combinations are possible, but that which appears to be most generally favored is to have twin reciprocating engines each driving their own screws exhausting into a single turbine driving a center shaft. The reciprocating engines exhaust at about atmospheric pressure, and the turbine used the expansion from that pressure down to the vacuum of the condenser, which may be 28 inches or 28½ inches. For maneuvering or going astern the reciprocating engines are used.

At present two large Atlantic liners are being built with the above arrangement for the Atlantic service, but it may be pointed out that the destroyer *Velox*, made in 1903 by the Parsons Marine Steam Turbine Co., Ltd., for the British Admiralty, was the first ship fitted with such a combination.

It may be mentioned that eight years ago there were only 25,000 H.P. of marine turbines afloat; two years ago there were 800,000 H.P., and now there are over 1¾ millions completed and under construction.—"Page's Weekly."

THE TACTICAL VALUE OF TORPEDO CRAFT.

The United States Navy has under construction four torpedo-boat destroyers of 902 tons full-load displacement, and Congress at its last session provided for ten more vessels of this general type, which will probably be between 1,000 and 1,200 tons full-load displacement. We also have under construction eight submarine boats, ranging in displacement from 274 tons to 500 tons when submerged; and Congress at its last session authorized the building of eight more submarines, at a total outlay of not more than $3,500,000. These boats will probably have displacements of not less than 400 tons when fully submerged. As can be seen, the "destroyers" and the submarines represent a very material increase to our torpedo craft, and the question is: In the light of experiments and maneuvers abroad, which type, the surface or the underwater boat, is likely to give us the better defensive return for the money expended?

Apart from the unquestionable offensive powers of the torpedo, *per se,* modern developments in the form of turbine propulsion, superheaters, and more accurate gyroscopic gears have added very materially to the range and the directness of travel. As a result, both the 18-inch and the 21-inch torpedoes have much longer effective ranges; the 18-inch being able to run 1,800 yards at a speed of 35 knots, while the 21-inch torpedo is able to cover a distance of 4,000 yards at a speed of from 26 to 27 knots. Searchlights as now installed upon modern naval vessels cannot be safely counted upon to pick up a low-lying torpedo craft at a distance of much over 1,500 yards, and it is therefore plain that the modern torpedo outranges the reach of the searchlight. Surface torpedo boats and destroyers are not exclusively designed for the use of torpedoes. Each of them carries a fairly considerable armament of rapid-fire guns, and it is evident that their torpedoes are essentially instruments of opportunity, and that that opportunity can come chiefly at night, and then under conditions more or less limited.

Extensive experiments conducted abroad have proved the utter impracticability of a successful daylight attack; the torpedo vessels being theoretically destroyed by the rapid-fire guns long before getting within torpedoing range. Accordingly, night attacks have become the object of most serious study, and with some measure of success.

During some recent maneuvers in the British navy, a problem of this sort was set the division commander of a flotilla of torpedo destroyers: A squadron of cruisers and battleships was sent to sea at night, and a division of destroyers, not informed of the whereabouts of the ships, was ordered to hunt them down and to attack them by means of torpedoes with collapsible heads. The torpedo was to be considered properly fired only when it had struck the hull of a designated ship; the captain of each torpedo craft being obliged to name the vessel chosen by him for attack, and to identify his vessel before firing the torpedoes. The net result of this experiment was that the torpedo boats discovered the vessels and were able to make their attack before their presence was observed by the battleships and cruisers, but not a single torpedo struck home, and no commander was able to state which of the enemy he had endeavored to hit. In order to strike a moving target, the torpedo must be so aimed that due allowance shall be made for the enemy's speed and the direction in which he is moving. These two elements in the triangle of fire are hard enough to estimate in broad daylight, and the difficulty is accordingly magnified by darkness, while atmospheric conditions and any dimness of light will make it hard to identify even well-known vessels. The results in the foregoing maneuvers need occasion no surprise, but they do point significantly to the desirability of securing some means of getting within torpedoing distance within the ranges of daylight, when the probabilities of successful attacks give ample reason of being for torpedo vessels. It is thus seen that the surface torpedo boat is practically denied the chance of doing effective service during the daytime,

while at night, except under limited conditions, she is a menace to both friends and foe, unless by some rare chance she be able to get safely within striking distance, and then to make sure that her target is the right one. The blinding effect of the searchlight is all too well known, and with a watchful foe so guarded, the opportunities of reaching a moving enemy are few and far between, because her speed and direction of motion can only be guessed at roughly.

The submarine torpedo boat seems to be the logical solution of the problem. Of course, their problem is the same as that of the surface boat, so far as properly calculating the direction in which the torpedo shall be aimed in order to compensate for the rate and direction in which the enemy is moving; but this is capable of solution through the medium of a proper observing instrument or periscope, and, again, this is an optical task which the Italians are said to have successfully accomplished.

Undoubtedly, underwater boats of the future will be divided into two broad classes; those for harbor and coast defense in the more restricted sense of the terms and those for offshore or seagoing purposes; the mission of the latter boats being not only to keep an enemy well to sea and beyond bombarding range of their guns, but also to accompany a battle squadron at a good cruising speed, and constitute its outlying defense when those ships are anchored in an unfortified port or improvised coaling base. Upon the resumption of the squadron's cruise, the submarines will be discharged of their duty of defense, and follow along in the rear of the big ships. Such would be the principal services of the seagoing submersible of displacements ranging from 300 to 600 tons, while the boats for strictly harbor and inshore protection would be craft of 200 tons or less, capable of holding their positions submerged for a maximum period of probably twenty-four hours. The seagoing submersibles would naturally have to have speeds of fully 15 knots an hour upon the surface, and a cruising endurance at a 10-knot clip of quite a thousand miles. This is not

calling for anything extraordinary in view of what has already been accomplished.

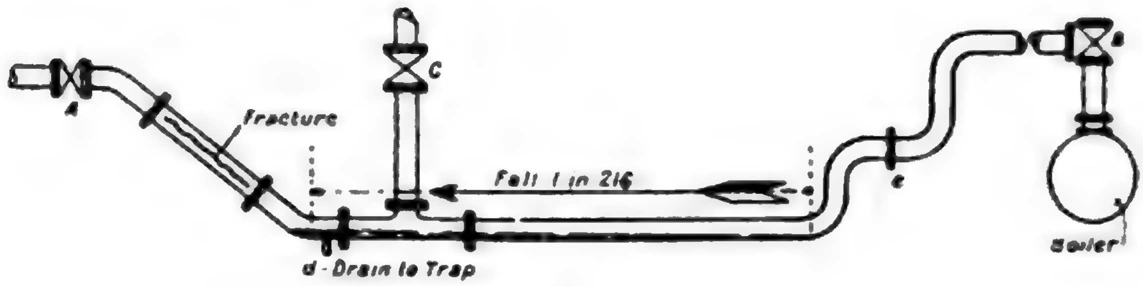
Reviewing these conditions in the light of the most recent experience abroad, may it not be justly claimed that we would do wiser by adding more to our flotilla of submarine vessels, and making of our destroyers craft of much larger displacement, so that they may properly serve the purpose of "scouts," for which a field of valuable daytime service does exist; making their torpedo equipment of secondary importance, and recognizing their chance of possible usefulness to be that of a remote opportunity?—"Scientific American."

WATER HAMMER IN STEAM PIPES.

We take the following article, on which we comment on another page, from Mr. Longridge's report for 1907 to the British Engine Boiler and Electrical Insurance Company, Limited:

Every year some lives are lost by the fracture of pipes or valve casings by water hammer. In 1907 the loss was heavier than usual. Six men were killed, three of them by one explosion. In nearly all the cases recorded since the passing of the Boiler Explosion Act in 1882 the water hammer might have been prevented if those who set it in motion—and in many instances suffered from its effects—had understood the probable consequences of their acts. It therefore seems worth while to call special attention to each of the twelve cases recorded in the Abstracts of Board of Trade Reports by describing the conditions existing at the time the water hammer occurred, and the specific act which caused it, in the hope that those who have to design steam mains, or to operate the valves and drains in connection with them, may avoid the pitfalls which these reports disclose. The sketches used for illustration are not copies of the drawings in the reports, but merely diagrams showing the particular features of the pipe arrangement which were contributory to the occurrence of the water hammer.

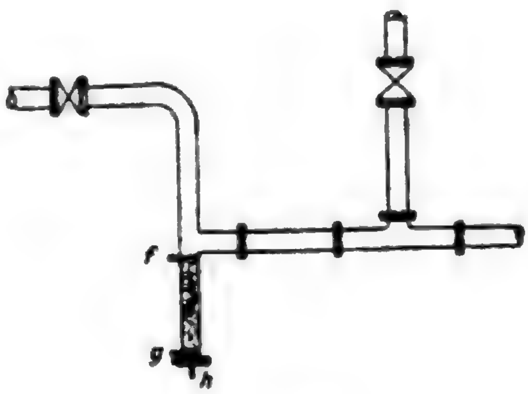
No. 1669.—Initial conditions: Pipes 250 feet long, newly erected and uncovered. Drain *d* blocked by cement jointing material and rust. Stop valve A to other boiler and boiler junction valve B shut down to re-make joint at *e*, valve C left open. Water accumulated in pipe before stoppage, cooled during stoppage.



No. 1669.

Act which caused fracture.—Opening valve B.

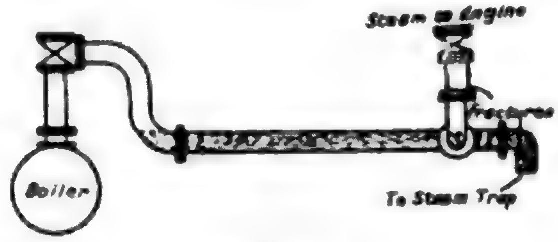
The mistake here was in relying on a steam trap for draining a new pipe. A large drain cock, without a waste pipe, should have been fitted close to the pipe. The arrangement of the pipe was bad; it should have been made as shown, with a well pipe provided with a small try cock, or some kind of float tell-tale, and a large drain cock, to be subsequently connected to a steam trap. The try cocks or float would have enabled the engineer to ascertain if the water were below the horizontal



No. 1669.

length of pipe before he opened the drain cock or the junction valve B. Try cocks, if used, must be very small, and opened for a very short time, otherwise the discharge from them may

be sufficient to disturb the surface of the water in the horizontal length of pipe, and thus start the water hammer they are intended to prevent. Floats will be referred to later.

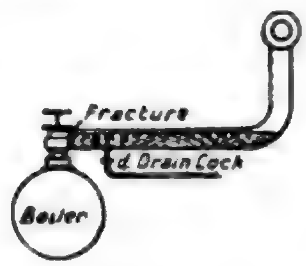


No. 1673.

No. 1673.—Initial conditions: Steam kept up on Saturday and Sunday, and boiler junction valves left open. Steam trap blocked. Horizontal length of pipe filled with condensed steam.

Act which caused fracture.—Opening valve to engine.

Here again the fault was trusting that the steam trap had kept the steam range clear, and opening the valve to the engine without shutting the junction valve. A well pipe, fitted with a small test cock or a float tell-tale, would have enabled the man to see if the pipe were clear.



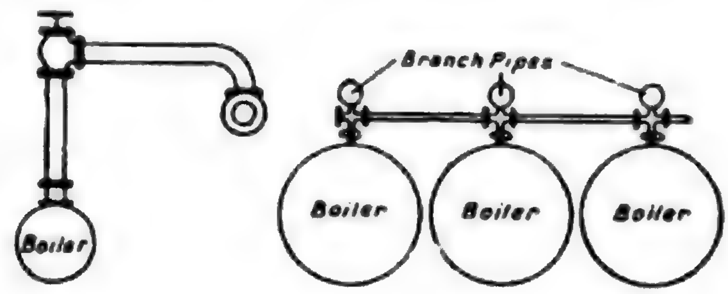
No. 1677.

No. 1677.—Initial conditions: Boiler off for cleaning, junction valve shut. Drain cock *d* left slightly open, and got blocked. Water accumulated in horizontal branch.

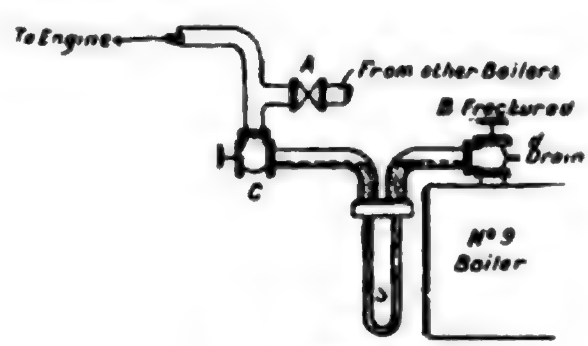
Act which caused the water hammer.—Man opened drain cock *d* full to blow out obstruction.

The fault was in opening the cock without first shutting the junction valves of all the boilers. Where there is more than one boiler the branch pipes should be fixed as below, or if this be impossible for want of head room, all the branches should be drained by large pipes without cocks or valves, leading into

a main pipe across the range of boilers, with a connection controlled by a cock to each boiler, as indicated by the diagram, so that when any boiler is stopped its branch pipe will drain into the other boilers.



No. 1678.—Initial conditions: No. 9 boiler off for three weeks, junction valve B closed, stop valve C very leaky, open at time of explosion. Drain *d* open, stop valve A, leading to other boilers, shut 15 hours before explosion. Superheater S contained water, and possibly also the 7-inch pipe up to the level of drain *d*.

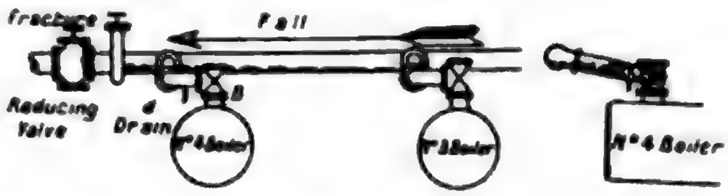


No. 1678.

Act which caused water hammer.—Opening stop valve A to give steam to engine.

The fault was in opening the valve A before closing the valve C. The man ought to have known that unless the valves B and C were absolutely tight there would probably be water in the superheater. He ought, therefore, to have shut the valve C before opening A, and left it closed with the water in the superheater till the fire was lighted in No. 9 boiler to boil it off. The drain *d* should, of course, have been fixed at the lowest possible point of the pipe.

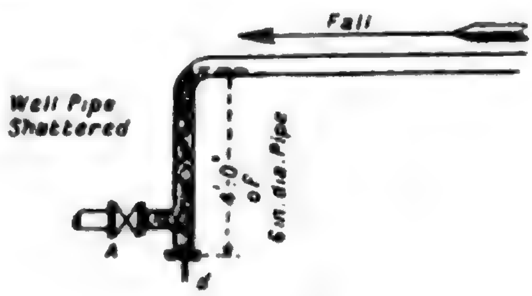
No. 1683.—Initial conditions: Nos. 1, 2, 3 boilers working; No. 4 boiler empty for thirty-one hours; drain *d* slightly open, sluice valve shut. Water accumulated in lower end of steam main and branch to No. 4 boiler, either through slightly opened drain cock getting blocked or through condensation in pipe exceeding discharge.



No. 1683.

Act which caused water hammer.—Opening sluice valve without shutting the stop valves in the other boilers. If the drain *d* had been cross-connected to the other boilers, as shown on the third sketch belonging to No. 1677, the steam main might have been kept free from water.

No. 1685.—Initial conditions: Steam left to condense in 90 feet of new uncovered pipe varying from 9 inches to 6 inches diameter during dinner hour; engine stop valve A shut, drain *d* shut.

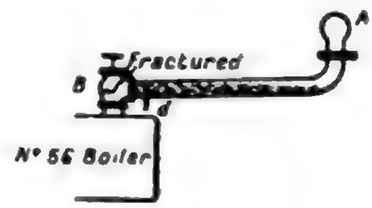


No. 1685.

Act which caused water hammer.—Opening the engine stop valve A.

The fault was in opening the engine stop valve before closing the boiler junction valve and opening the drain *d*. With the well pipe overflowing into the steam main, it would have been dangerous to open the drain *d* without first shutting the boiler junction valves. A try cock or a float tell-tale would have shown whether the well pipe was full.

No. 1700.—Initial conditions: Boiler No. 56 empty, junction valve B shut, drain *d* shut. Other boilers in connection with steam main A working. Condensed steam accumulated in branch pipe, and got cool.



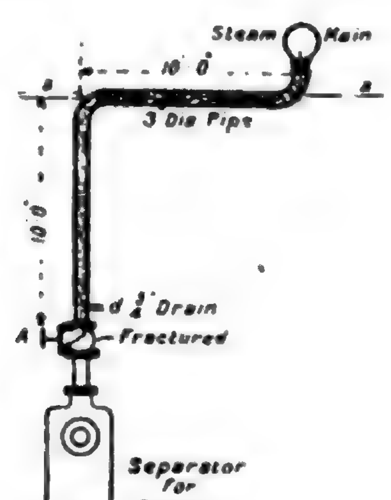
No. 1700.

Act which produced water hammer.—Opening drain *d*.

The fault was in opening the drain without shutting off steam from the main A. The drain *d* should have been cross-connected to other boilers, or, at least, to one of them, as shown in the third sketch belonging to No. 1677.

No. 1717.—Initial conditions: Stop valve A shut, drain *d* shut, 3-inch pipe full of condensed steam at low temperature.

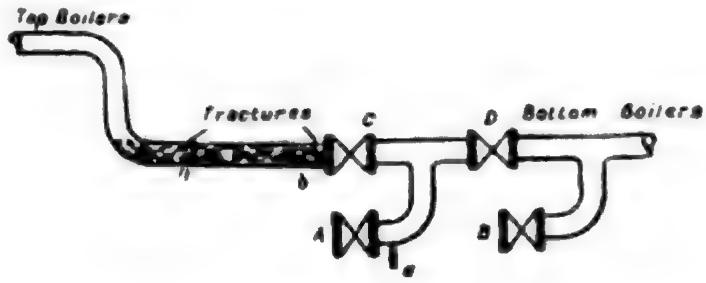
Act which caused water hammer.—Opening drain *d* two turns, giving an opening of 0.137 square inch for two minutes (?), or, if this did not lower the water level in the 3-inch pipe to *a a*, opening the stop valve A after the drain had been open two minutes (?). Whichever of these acts lowered the water level in the 3-inch pipe to *a a* caused the water hammer.



No. 1717.

The fault was in opening the drain or the valve without shutting the steam off the steam main. The drain should have been trapped and left open, but the better plan would have been to have placed the stop valve A close under the steam main.

No. 1722.—Initial conditions: Stop valve C shut, *d* open. Engine stop valve A open, drain *d* shut. Condensed steam had accumulated and cooled in pipe *a b*.

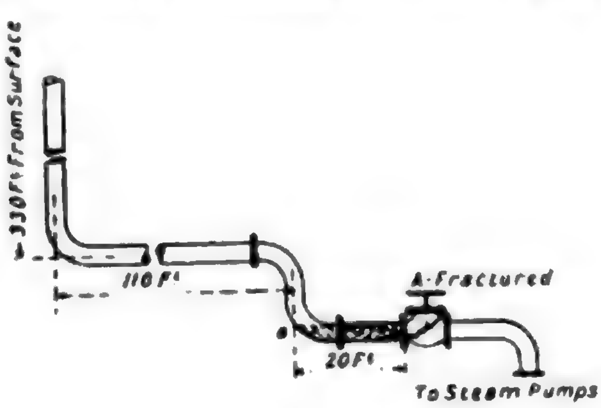


No. 1722.

Act which caused water hammer.—Closing valve D, opening drain *d* and valve C.

The fault was in opening C before closing the junction valves on the top boilers. To avoid the necessity of having to close these valves before opening the valve C, the pipe *a b* should have been fitted with a large drain leading to a steam trap, which would have kept the pipe clear so long as the trap acted. But the better plan would have been to have had a well pipe close to C, drained by a trap, and fitted with a float telltale or small test cock, or both, as above described, to enable the man in charge to ascertain whether the pipe were free from water before opening the valve C, and to warn him to shut the junction valve on the top boilers if it were not.

No. 1727.—Initial conditions: Valve A shut, lower part

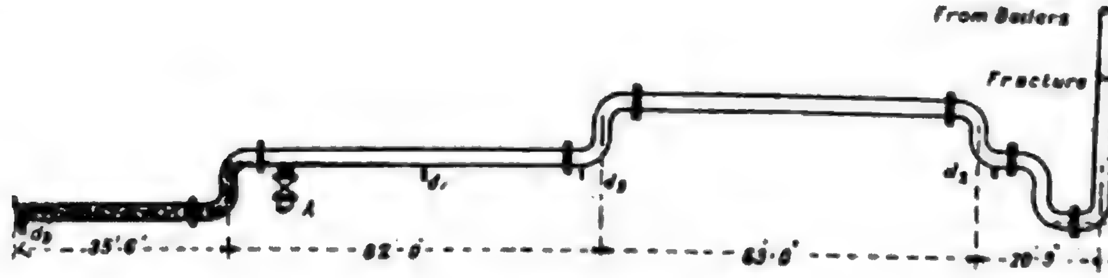


No. 1727.

of pipe filled with water, the result of half an hour's condensation in steam pipe from surface to bottom of pit.

Act which caused water hammer.—Opening valve A to pumps.

The fault was in opening A before closing the boiler junction valve. A water hammer was almost unavoidable in this case, because it was impossible to empty the pipe *a b* owing to the seat of the valve A being level with the center of the pipe. The only chance would be to shut the boiler junction valve, then open A, then open the junction valve a very small fraction of a turn to prevent a vacuum in the pipe and allow the water to run out through the drain cocks on the pump cylinders down to the level of the seating of the valve A, and then to open the junction valve a little wider, just sufficiently to cause agitation without violent motion of the water remaining in the pipe, in order to heat this water. With great care it might be possible to heat the water sufficiently to prevent water hammer, but considering the great length of steam pipe this is very doubtful. Had the valve A been a sluice valve, all the water might with care have been got rid of through the drains of the pump cylinders without accident. There should, of course, have been at least a drain at the lowest point of the pipe, which should have been open whenever A was shut; but the proper thing in such a case is a well pipe with try cocks or a float telltale.



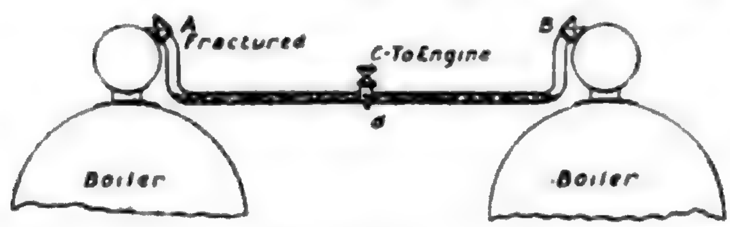
No. 1737.

No. 1737.—Initial conditions: Small valve A shut, drains d_5 shut, drain d_3 d_2 open, boiler junction valve open. Condensed steam accumulated and cooled in end of pipe.

Act which caused water hammer.—Partly opening small

valve A and drain d_5. The water hammer was not hard enough to knock off the end of the pipe, but it shook the range sufficiently to break it about 200 feet back.

Again, the fault was in attempting to drain off the water without shutting the boiler stop valve. The drain d_5 should have been trapped, or better still, there should have been a well pipe with tell-tale at the low end of the range.



No. 1738.

No. 1738.—Initial conditions: Engine standing for some hours, valves A, B, C shut, drain *d* shut. Condensing steam leaking past A and B accumulated and cooled in pipe.

Act which caused water hammer.—Opening drain *d* and easing junction valve B.

The first fault was in keeping *d* shut with leaky stop valves; the second in opening B before all the water had escaped from the pipe.

In all these cases the water hammer was caused by the disturbance of a comparatively large water surface in a horizontal or inclined pipe, in which the water was capable of moving; and wherever there is such a water surface water hammer will almost certainly be produced if that surface be disturbed by the opening of a valve or a drain.

Therefore, whenever there is any doubt about the presence of water in such a pipe it is dangerous to attempt to drain the water away without first shutting steam off the pipe. From a vertical pipe water can be drained with little risk, because the water resting on the bottom end of the pipe cannot be set in motion.

Mr. Longridge suggests an ingenious form of float telltale to indicate the level of water standing in a down pipe, which is well worth the attention of steam users.—"The Engineer."

MARINE BOILER EXPLOSIONS.

[From the Board of Trade Reports.]

Report No. 1,728 deals with a mishap to the boiler of the trawler *Balmoral Castle*. The vessel is engaged in trawling from Aberdeen, and on the 17th December last she proceeded to the fishing grounds off that coast. The following day the fishermen were mending their nets for shooting the trawl, the engines being stopped and the boiler steam being maintained at 140 pounds, when about 1 P. M. a crack occurred at the knuckle of the front flange of the port furnace. It measured 9 inches long by about $\frac{1}{32}$ inch in width, and the escape of steam and water was sufficient to force the attendant to retire on deck. As it was impracticable to effect any repairs, the vessel was towed by another trawler back to Aberdeen. When the defective part was being cut out it was found that the mark extended for 27 inches. The cause of the casualty was considered to be due to the rigidity of the furnace not being adapted to the stresses caused by considerable fluctuations of temperature, consequently the continued expansions and contractions gradually developed the crack.

Report No. 1,731 deals with the blowing out of a screwed plug from the bottom of the main boiler of the *Ingram* last November. The vessel left Beckton, in ballast, about 11 A. M. on the 6th of that month, bound for Tyne Dock, and about an hour later there was a sudden escape of water and steam from the bottom of the boiler, and the water level sank quicker than the donkey and auxiliary feed could make up. When the boiler had emptied itself a hole about $1\frac{1}{2}$ inches in diameter was found in the bottom of the shell, but the plug could not be found. It appears that the thread was fine, and leakage had caused corrosion of the plate, the result being as stated. A through bolt with washers was fitted and the vessel completed her voyage.

Report No. 1,734 deals with a mishap to the main boiler of the *Derwent*. The vessel left Cardiff for Cowes, with a cargo of flour, about 10 P. M., on 7th January last. The boilers were leaky and steam could not be maintained, so the vessel

returned to Barry Roads; at 5 P. M. on the 9th a fresh start was made, but three hours later water commenced to run out of the port furnace. By 2·30 the following morning the leak had increased so much that the donkey had to be put on from the sea, and at 3 A. M. there was an explosion in the port combustion chamber, steam and water pouring out of the furnace mouth. The fires were drawn, and a later examination showed a hole had been formed in the bottom plate of the combustion chamber. The vessel drifted about till 10 A. M., when she was taken in tow to Barry. It was then found that the boiler was in a very defective condition; the vessel was consequently stopped for a new boiler.

Report No. 1,735 deals with a steampipe mishap on the *Dunbar* in November, 1906. The pipe was of solid-drawn copper, $4\frac{3}{4}$-inch bore, and about $\frac{1}{4}$ inch in thickness. The vessel is fitted with two single-ended boilers, with separate pipes to the engine stop-valve chest. She left Cardiff in October, 1906, for Bombay with a full cargo of coal, and arrived at Suez in November. She cleared the canal about 4 P. M. on the 2d of that month, and half an hour later there was a slight escape of steam from the starboard main steampipe near the boiler stop valve. The chief engineer found that the pipe was fractured circumferentially for a length of 10 inches near the flange. The steam pressure was immediately reduced from 170 to 90 pounds, and the vessel put back to Suez where the pipe was taken ashore, $1\frac{3}{4}$ inches in length cut off the end, the flange rebrazed on the shortened pipe and a distance piece made to make up for the shortened length. The pipe has since given no trouble. It seems that on the voyage previous to the explosion the vessel encountered bad weather when in ballast, causing considerable vibration of the engines. This had evidently severely stressed the pipe, causing its subsequent failure.

Report No. 1,736 deals with an explosion of the auxiliary steampipe leading to the steering engine on the *Ardmount*. The vessel was on a voyage from Melbourne to Antwerp, and was making for Albany for bunker coal, being about 36 hours

distant at 12·10 A. M. on 1st November last. The chief engineer, on going off watch at midnight, heard a noise of escaping steam. Some lagging was removed from the pipe in question and a small longitudinal crack was seen in the middle of the pipe. The chief and third engineers were below looking for a clamp to stop the leak, when the pipe fractured with a loud report, the opening being 24¾ inches long and the greatest width of the opening being 7⅛ inches, the shock of the explosion causing the pipe to break away from one flange. The third engineer escaped on deck, and the chief got up the tunnel, taking the Chinese greaser with him. The steam was shut off and the hand-steering gear shipped and used till the following morning, when steam was raised in the donkey boiler and that range of pipes used till Albany was reached, where a new pipe was fitted. The copper was analyzed and tested, and found to be deficient in ductility.

Report No. 1,738 deals with an explosion of a stop-valve chest on the dredger *Beaufort* last December. The vessel was thoroughly overhauled at Barrow in August, last year, and on completion proceeded to Heysham, and was there employed on tide work, working four hours and idling eight hours. Owing to the arrangement of the steam pipes, a large amount of condensed water accumulates in them when the stop valves are closed. On 11th December the vessel ceased work at 5 P. M., and just before 1 A. M. on the 12th the second engineer proceeded to get all ready for starting again. He opened a drain cock and then opened one of the boiler stop valves slightly, to assist in driving the water out of the pipes. The immediate result was the driving of the water in the pipes to the other stop valve, where it broke the top flange off the chest.

Report No. 1,741 deals with a casualty to one of the main boilers on the *Wileysike* in December last. The vessel left Troon on the 17th of that month for Genoa, with a cargo of 3,100 tons of coal. About 4·30 A. M. on the 20th, when the vessel was about 25 miles off the Scilly Islands, water was found to be flowing out of the two lower furnaces of the star-

board boiler. The stop valve was closed, the fires drawn, the safety valves eased and the blowdown cock opened. At 8 A. M. the chief and second engineers went into the center chamber and found a crack in the bottom corner of the back tube plate, extending to a rivet hole, from which the rivet had been blown out. The vessel put into Falmouth with steam from the port boiler. The cracked plate was cut out there and a riveted patch fitted. The plate had thinned locally by corrosion, and in addition the stresses due to expansion and contraction had been severe.

Report No. 1,746 deals with a mishap to the boiler of the steam fishing vessel *Rhodesia* in December last. She left Grimsby on the 13th of that month, and the following day, about 11·30 P. M., when steaming full speed, about 240 miles off Spurn Point, the lower front-end plate cracked circumferentially for a length of 18 inches at the root of the flange by which it was attached to the port furnace. This was due to the variations of temperature, causing deterioration in the quality of the metal by panting action.

Report No. 1,747 deals with the fracture of a stop-valve chest on the *Kinfauns Castle* on 23d February last, the vessel being in latitude 28° 14′ S., on a voyage from Southampton to Cape Town. The vessel left her home port, using steam from five out of her six boilers. One of these was subsequently shut off and steam raised on the one not previously in use, and it was on coupling this one to the main range that the explosion occurred, owing to water hammer.

Report No. 1,754 deals with an explosion from a feed-check valve chest on the *Suir*, one of the River Liffey steam barges. This was a very simple mishap. The stop pin in the spindle to prevent the thread being screwed out of the bridge had come out unnoticed, the result being that on opening the valve full, the thread was screwed out, and the spindle was then blown out of the cover of the chest.

Report No. 1,756 deals with a mishap to the steam tug *Clarissa*. The vessel left Cardiff on 1st April, last, towing a sailing vessel. The tow was cast off at midnight when off

Lundy Island and the tug remained in the vicinity "seeking" till the 4th, when she made for Cardiff. At 2·30 P. M., when the vessel was six miles off Ilfracombe, the driver, who was on deck, noticed a whitish color in the funnel smoke. On going below he found water running out of the starboard furnace to such an extent that he had to draw the fires. The vessel drifted into shallow water where she dropped anchor, and was subsequently towed into Ilfracombe. The cause of the trouble was a defective patch on the bottom of the combustion chamber, which was much wasted owing to leakage.

Report No. 1,757 deals with an explosion from a boiler on the *Kura* last March, whilst on a passage from South Shields to Kustendje. The vessel left Tyne dock on 5th March, in ballast, and all went well till 7·50 P. M. on the 17th, when the second engineer observed steam coming through crevices around the door in the bulkhead between the engine and boiler rooms. He partly opened the door, but was driven back by steam. As large volumes of steam were also coming up the stokehold fiddley, the attention of those on deck was drawn to the matter and they turned out the other engineers. The safety valves on both boilers were lifted and the engines kept running to work off the steam. Half an hour later the engineers were able to get into the stokehold, and one fireman was found scalded to death. The other fireman on watch was scalded on the face, but had escaped up the stokehold ladder. On examining the port boiler, a back-end nut was found missing from a tube stopper in one of the stay tubes, and it had apparently been blown off, owing to the threads getting defective. It seems that the stay tube was broken and the area of the stopper was only one-fourth of the area of the tube, hence the stress was excessive, and this, coupled with the fact that the stopper had been in the tube more than twelve months, which was an error of judgment under the circumstances, resulted in the explosion.

Report No. 1,762 deals with a mishap to the boiler of the *Tweed*, a coaster employed between Berwick and Leith. The vessel left the former port on 22d June last, about 10 A. M.,

and an hour and a half later steam and water was noticed to be coming from the starboard furnace. The fires were drawn, the steam worked off and sails set till 7·30 P. M., when the anchor was dropped; a small hole was found at the back end of the furnace, which was stopped with a bolt and washers, after which the vessel proceeded. Leakage from the adjacent seam had caused locally corrosion of the plate.—"The Steamship."

FIRING WITH COAL AND OIL FUEL IN COMBINATION.

A process of using solid and liquid fuel together is now being demonstrated at the Caledonian Engine Works, Pentonville, London, N.

We give below the records of three tests, from which it will be seen that highly satisfactory results have been obtained by the new system.

The first test was made with the experimental boiler fired by means of a furnace in the ordinary way; the second after turning over to the new system, while the third test was made for the percentage of CO_2 in the flue gases, also after turning over, but too late for a comparative test for CO_2 being made with the furnace in the ordinary condition. But the fact that smoke was emitted half the time during the first test shows that the CO_2 was very low under the ordinary firing conditions.

The boiler is worked in the open without any lagging, and the coal used in the first and second tests was of a very inferior quality. The equivalent evaporation in the first case was 6.35 pounds per pound of coal, but this was only possible with the emission of objectionable smoke half the time, whereas, with the new process the equivalent evaporation was 10.03 pounds per pound of coal + about 4 per cent. of oil, with no smoke emitted.

The third test was made first, with steam alone passing through the apparatus. The coal in this instance was ordinary dross coal of rather better quality than that used in the first and second tests. An average of $11\frac{1}{2}$ per cent. CO_2 was obtained. About 4 per cent. of oil was then turned on, when

the average percentage of CO_2 increased to over 14 per cent., 14¾ per cent. being registered in one instance.

When such an advantage can be obtained immediately by merely turning a tap, it is evident that there will be a large demand for the new process, especially on board ship, in electric generating stations, dye works, paper mills, and all works where there is a liability to sudden demands for an increased supply of steam being made upon the boiler.

The essential feature of this process is that the oil is gasified in retorts which are arranged in the furnace. The oil is first injected into the retort from the front of the furnace by a jet of steam through a special nozzle, and from there it travels down the center of the furnace to the end of the fire, then along the back of the fire and returns to the front, being all the time within the heated retort. On reaching the front of the furnace in a gasified state it ignites and is blown down on the top of the coal fire, when an intensely hot flame is created in the whole of the furnace. The proportion of oil and coal can be varied at will.

The process is being introduced by Direct Gas Fuel, Limited, 17 Victoria Street, Westminster, S. W.

RECORD OF TEST WITH SOLID FUEL ONLY ON CORNISH BOILER 3 FEET 9 INCHES DIAMETER BY 12 FEET LONG, FLUE 2 FEET DIAMETER.

Situation	Caledonian Engine Works.
Date of test	Friday, 19th June, 1908.
Time of starting, 2 P. M. / Time of finishing, 6 P. M. } Duration of test, hours	4
Total water evaporated, pounds	1,670
Total coal charged, 336 pounds ash, 30 pounds net, pounds	306
Fuel oil	*Nil.*
Grate area, square feet	7
Net solid combustible burnt per square foot of grate per hour, pounds	10.92
Water evaporated per square foot of grate, per hour, pounds	59.6
pound of solid combustible, pounds	5.4
Boiler pressure, pounds	55
Temperature of feed water, degrees Fahrenheit	70
Water evaporated per pound of solid combustible from and at 212 degrees Fahrenheit, pounds	6.35
Quality and amount of smoke, dark brown	½ hour in each hour.
Natural draft of chimney, poor; inch, about	0.35

Temperature of outside air, shade, degrees Fahrenheit	70
solar, degrees Fahrenheit	109
Wind	Light N. W.
Barometric pressure	29.83
Description of coal used: Poor quality nuts and about 33 per cent. dust. Cheapest to be had in London, 10 per cent. ash, B. T. U	11,400

Remarks: Boiler worked in open. No covering composition.

RECORD OF TEST WITH SOLID AND LIQUID FUEL COMBINED ON CORNISH BOILER 3 FEET 9 INCHES DIAMETER BY 12 FEET LONG, FLUE 2 FEET DIAMETER.

Situation	Caledonian Engine Works.
Date of test	Friday, 10th July, 1908.
Time of starting, 2·15 P. M. / Time of finishing, 6·15 P. M. — Duration of test, hours	4
Total water evaporated, pounds	3,300
Total coal charged, 440 pounds ash, 53 pounds net, pounds	387
Oil fuel, pounds	16
Grate area, square feet	6
Net solid combustible burnt per square foot of grate per hour, pounds	16.12
Water evaporated per square foot of grate per hour, pounds	137.5
pound of solid combustible, pounds	8.52
Boiler pressure, pounds	60
Temperature of feed water, degrees Fahrenheit	70
Water evaporated per pound of combustible from and at 212 degrees Fahrenheit, pounds	10.03
Quality and amount of smoke	No smoke.
Natural draft of chimney, poor; inch, about	.35
Temperature of outside air, shade, degrees Fahrenheit	72
Wind	Light S. W.
Barometric pressure	29.83
Description of coal used: Poor quality nuts with about 30 per cent. of dust. Cheapest to be had in London, 12 per cent. ash, B.T.U.	11,400

Remarks: Boiler worked in open. No covering composition.

PATENT FURNACE FOR BURNING COAL AND OIL TOGETHER.

Tests made 13th August, 1908, by Mr. Wakeham, of Messrs. Sanders, Rehders & Co., Ltd., with the Sarco CO_2 machine.

The following percentages of CO_2 were obtained previous to the oil being fed, but with the steam jet on. These tests were taken about every two minutes: 11½, 13, 12, 11, 11½, 12 per cent.

A number of tests were then taken with the assistance of the oil, the periods between each test being the same as before. A marked improvement was shown, the figures being

as follows: $12\frac{1}{2}$, 13, 14, $14\frac{1}{2}$, $14\frac{1}{2}$, $13\frac{1}{2}$, 13, $14\frac{3}{4}$, $14\frac{1}{2}$ per cent.

The coal in this case was ordinary Derby nuts, about 13,400 B. T. U., plus about 4 per cent., oil about 19,300 B. T. U., 920 specific gravity, and 150 degrees flash point. —"The Steamship."

THORNYCROFT PARAFFIN MOTORS FOR THE ROYAL ITALIAN NAVY.

These engines, which are to be installed in two twin-screw submarine boats, are constructed in four-cylinder units, bolted together, making eight cylinders on each shaft. The dimensions of the cylinders are 12 inches diameter by 8 inches stroke.

They are totally enclosed and lubrication is forced to all bearings, those on the crankshaft, and also the bottom of the crankcase, being water-cooled.

In addition to this, the pistons and crank case generally are continuously cooled by sucking cold air, which is drawn through by an exhausting fan.

Facilities are provided for the removal and replacement of the pistons and connecting rods through the doors in front of the engine, thus rendering removal of the cylinders and access from the back of the motor unnecessary—an advantageous feature for submarine boats.

Cooling water is circulated by a separately-driven centrifugal pump, driven by either an electric motor or a small oil motor using the same fuel as the main engine. A great advantage of this method is that the motor may be cooled more rapidly after running, in case examination or adjustment become necessary. The separate drive also allows of a close regulation of the quantity of water to suit the needs of the engine, according to the nature of fuel used.

The special paraffin vaporizer is fitted with a variable exhaust by-pass, so that the temperature may be exactly graduated to the needs of the particular fuel used. This is very essential, as the oils used for fuel vary so greatly in the amount

of heat required to vaporize them, and excess of heat is as harmful as too little. With a proper regulation of heat the engine or vaporizer never requires to be cleaned, as there is no tar deposit. Trouble on this score is absolutely non-existent with these engines.

An entirely novel feature is the reversing mechanism. Instead of the usual method of using a double set of cams for running in either direction, the cam shaft is so arranged that, whichever direction the engine itself runs, the cam shaft turns in one direction only, and to provide for this a reversible bevel drive, with positive clutches, is fitted.

Starting in either direction is effected by means of compressed air, the valves controlling which are cut off immediately the engine is firing.

Low-tension magneto ignition, and distributor, are fitted in conjunction with a special form of make-and-break gear in the cylinders.

The consumption of fuel is very low, being about .7 pint of paraffin or petrol per brake horsepower per hour.

The engines are designed with ample bearing surfaces, and are in every way suitable for heavy continuous service.

The total weight per four-cylinder set is 70 cwts.

The following table of results of a three-hours' trial is of interest:

TRIAL OF F4 1 AND 2, 8-CYLINDER 12-INCH DIAMETER BY 8-INCH STROKE. REVERSING.

Fuel used, Phoebus paraffin, S.G., 0.820
Consumption, 0.66 pint per B.H.P. per hour.

Time from start, hours	B.H.P.	Revs.
0	324	550
0½	328	555
1	340	590
1½	327	595
2	318	595
2½	318	600
3	324	600

Average revolutions per minute, 582.5
Average power, 325.5 B.H.P.

ENGINEER OFFICERS.

Mr. Charles de Grave Sells, Genoa, the well-known engineering writer, has contributed a very important article on Engineer Officers to the new edition of "Fighting Ships," 1908. The author says that the dearth of experienced engineer officers in the United States Navy increases, and the Chief of the Bureau of Steam Engineering returns to the matter in his annual report to the Secretary of the Navy. He calls attention to his special report on the instruction of young line officers in engineering, and states as follows:

"In this report the necessity of officers specializing in engineering is discussed, and mention made of the success which has attended the performance by officers of the line of all engineering duty on board ships in commission.

"This duty on board ships in commission is primarily the care and manipulation of machinery, for which the eminently practical education in engineering obtained at the Naval Academy is a most fitting prelude, and reports received from commanding officers bear witness to the success of this plan of having engineering duties performed by officers of the line.

"That certain officers should be given further instruction in engineering, in other words, should specialize in engineering, requires no argument, as the nature of the duties demanded of them make plain the necessity. These duties, other than those on board ship, are: Heads of departments of steam engineering at the various navy yards and stations; inspectors of machinery at private building plants; inspectors of material at the numerous manufacturing establishments engaged in work for the Government; the designing of machinery at the Bureau; and the inspection of detail designs submitted by contractors, in order to make sure that the requirements of the specifications are complied with in every particular. For these positions an officer must be thoroughly conversant with the profession of engineering, as upon his judgment depends the success of the machinery installation of our ships, as well as the economical expenditure of large sums of money.

"The designer of machinery must not only be familiar with all the elements of machine design, with current and best practice, but must have that intimate knowledge of the needs of arrangements and installations which can be obtained only by association with the finished product at sea. It is for this reason that the most successful designers of marine machinery are found among those engineers who have had sea experience, who have stood a watch in the engineer department of a vessel in commission, and who have had their existence made miserable by the faulty and academic design of an engineer who has not had experience at sea. On this account the Bureau has always opposed the separation of the designing and of the operating engineer, and it believes that the result of its policy has been attested by the success of its designs. Even where the details of the design are left with the builder, the Bureau keeps a rigid watch over them by a critical inspection of the details submitted before work is begun, this inspection not infrequently resulting in important modifications, and in some cases to absolute disapproval of certain details.

"That this work may be done, and done properly, officers with a natural bent for engineering should be encouraged to 'specialize in engineering,' and should be given the instruction necessary for them to attain that end.

"Unfortunately, the number assigned to this important work has never been large enough to meet the demands of the service, and during the past year, it was far below the number that should have been detailed. But it is upon this body of officers that the department must look for the proper performance of the important duties enumerated, and it is of the greatest importance that the Government should have among its officers a large number of specialists in engineering.

"Engineering knowledge is a necessity for the modern naval officer, and the Navy must have engineers, no matter what they are called."

Mr. Sells goes on to say that—

"A somewhat similar state of affairs seems likely to prevail in the British Navy, and it is looked upon as such a grave

menace to its engineering efficiency, that the Engineering Institutions of England and the leading technical periodicals have taken up the matter seriously, and urge something being done without delay to remedy the trouble.

"The Institutions advocate an independent corps of Royal Naval Engineers, who would be trained as engineers, and who would devote their whole lives to engineering, these officers to have control in their own department, but in no case to succeed to the command of ships. To anyone with an intimate knowledge of the matter, this arrangment is not only a reasonable one, but the only one that is certain to be successful. The decision of the authorities, however, was that there should be fusion of the deck and engineer branches, and that officers in the engineering branch should have opportunities of succeeding to command, equal to the officers of the gunnery and torpedo branches. This is a very pretty idea in theory, but in practice it will assuredly lead to a decline in the specialist efficiency of both branches, nor has this 'succeeding to command' of a vessel been asked for, nor is it looked upon as in the slightest degree desirable, by an engineer who has a love of his profession. The new systems of training seem to be based throughout on the idea that all the duties of the Navy should be more or less common, with the result that in some cases, important duties are intrusted to people who are inefficiently trained for them, and in the case of engineering duties, to those who cannot possibly be as well versed in mechanical matters as the present engineering staff. The President of the N. E. Coast Institute of Engineers, in the opening address of the current session, specially called attention to one effect of the new departure. He stated that a recent order of the Admiralty had taken the mechanical charge of the gunnery and torpedo machinery of the fleet from the professionally-trained engineer branch, and given it to the mechanically-untrained gunnery and torpedo branches, and that the new arrangements had already in a notable case produced serious inefficiency, for in one of the latest battleships it had been found impossible to work the guns or to hoist up the ammunition after the machin-

ery had been for a short time in the hands of untrained men, and accordingly the engineer staff had to be requisitioned, and work day and night to get the gun gear in working order before the vessel could do her battle practice.

"The details of the new scheme provide for the cadets being rated as midshipmen on completing their training. they will then serve for a period of three years at sea, during which period they will work with the executive officers for training in deck duties and seamanship, and with specialist officers for training and instruction in gunnery, torpedo, navigation and pilotage, and engineering, a special proviso being made that one-third of the time is to be spent with the engineer officer.

"During the time they are attached to the engine-room department, the training is to be as follows: To learn the methods and practice adopted in harbor for the care and maintenance of the machinery; to acquire the knowledge and experience which will enable them to take the duty of engineer officer of the watch; to see such repair work as is going on in any department, and take part in examination of the hull and machinery; to take advantage of such opportunities as present themselves of seeing engineering operations in the dockyards; to keep an engineering notebook with descriptions and sketches; and to make acquaintance with the accounts kept of the stores, and the engine-room register and defects list.

"After three years they will be examined for the rank of lieutenant, when amongst other qualifications they will have to present a certificate showing that they have practical knowledge of engine-room duties, and that they have satisfactorily performed the duty of engineer officer of the watch.

"The examination is to consist of the five following compulsory subjects: 1, Seamanship; 2, navigation and pilotage; 3, engineering; 4, gunnery; 5, torpedo.

"If they pass in these five they may take up at least two of the following voluntary subjects: Practical mathematics, mechanics and heat, electricity, advanced French, German, Italian, Spanish, Russian or Japanese, and naval history.

"They must then serve not less than two years as commis-

sioned officers at sea, and at the end of this service officers will be selected to specialize in the various branches: Gunnery, torpedo, navigation or engineering, and these will attend a course of two terms, approximately six months, at the Royal Naval College at Greenwich.

"The result of all this may be excellent officers with a certain amount of engineering experience, but engineers in the full sense of the term they cannot be. They may be able to get along well enough in peace time and as long as things go all right, but in time of war will come the need of instant decisions, when there is no time or opportunity to sit down and think what would be the best thing to be done, and it is then one must rely on that thorough experience, which through years of practical work has become a second nature. This experience can only be ingrained into one by beginning to be an engineer when young, and the habit is then formed and grows of 'thinking engineering,' a habit it would be difficult, if not impossible, to acquire after one's tastes and habits are formed, and when, after all, engineering is only one of five subjects equally claiming one's thoughts, and to the average naval officer the least appealing of them to his tastes.

"It is to the life-long experience of its present engineer officers that the British Navy owes its brilliant successes of recent years, turbine engines, water-tube boilers, and liquid-fuel burning, and it is intensely to be regretted that the high attainments and services of these officers are not more appreciated.

"There is another very serious side to this question; the Engineer-in-Chief of the U. S. Navy in his report especially insists on the point that the engineer officer should be better informed than his subordinates, as otherwise he is 'worse than useless.' The inevitable result of such a hybrid training for engineer officers as is now proposed, cannot but result in placing them to a large extent in the hands of the engine-room artificers, and little by little these men will be doing the real engineering work of the Navy. One day they will realize this fact, and they will naturally ask for the position and pay due

to their responsibilities, and so the old troubles will again be met with.

"When this is borne in mind it will be well understood the dismay with which the new policy of the British Admiralty is regarded, relative to this splendid body of men, and that it is considered that there is "a serious danger to engineering efficiency in the policy of lowering the status of the artificers, and in placing stokers as engnie-room watch keepers, instead of the present mechanically-trained and skilled engine-room artificers."

To sum up the matter: that the future officers of the Navy should begin their careers together and have identically the same studies to begin with, is an excellent idea, and the foundation thus laid should be a good one, but naval engineering is too large a subject for it to be shared with all the rest of the subjects that a naval officer's career embraces; it requires *all* his efforts, *all* his aims, and the most of his time, and must not be considered merely one of several subjects and by no means the most important of them.

Let the matter be looked at fairly; the time a naval officer spends in the engine room after he goes to sea is just so much time lost to him, and it had far better be employed in perfecting his practical knowledge of seamanship, navigation, pilotage, gunnery and torpedo work, and surely any one will agree that these subjects are more than sufficient to take up his whole time.

In like manner the time an engineer officer spends in acquiring the practical knowledge of the above-mentioned subjects, is just so much time lost to him, and any true engineer will tell you that life itself is not long enough for him to acquire a full knowledge of his profession and all it embraces; he is ever learning, and the hours of the day available are never sufficiently long enough for his practical work and studies.

There is the work of the executive officer, who should have full command of the ship as a whole and control of the men of his department, and there is the entirely distinct work of the engineer officer, who should have control of the men of

his department. The duties of these two are quite different, no good can possibly come from mixing them up together, and it is an all-round loss, and the sooner it is recognized that this is so, the better it will be for the efficiency of any navy.

The engineer should be trained as such, he should devote his whole life to his profession, and he should be an engineer first, last and all the time. In this way only can real progress be maintained.—"The Steamship."

ENGINEERING AND SHIPBUILDING.

Mr. James Denny, as President of the Institute of Marine Engineers, London, delivered his address at the opening meeting of the session on 5th October. Mr. Denny is a member of the well-known Dumbarton firm and is one of the greatest living authorities on Marine Engineering and Shipbuilding. He took for his subject some recollections and lessons and their application, drawn from an experience of fully forty-three years of marine engineering. He said, the changes that have occurred during this period, the advances that have been made in marine engineering, will undoubtedly compare with the changes and advances made by any other industry in the country. Perhaps the progress during the period being dealt with may be illustrated if we take two vessels, both for the same owners, the British India Steam Navigation Co.; one of these, the *India,* built in the early sixties, and the other, the *Rewa,* built two years ago. The *India* was 230 feet long by 30 feet beam, about 1,000 tons, and the *Rewa* 455 feet long by 56 feet beam, and about 7,000 tons. The *India* was fitted with one simple two-cylinder engine, 46-inch cylinders by 3-foot stroke, horsepower about 800; the water consumed per I.H.P. must have been approximately 30 pounds, but no accurate observations were then taken. The *Rewa* is fitted with three turbines with a shaft horsepower of about 10,000, and the water per shaft horsepower is 15 pounds for all purposes at the maximum speed. The *India* had two flat-sided boilers for 25

pounds pressure, with natural draft; the *Rewa* had two double-ended and four single-ended boilers of the cylindrical type, 155 pounds pressure, with forced draft. The speed of the *India* on trial was about 10 knots, and of the *Rewa* touching 19 knots. The *India* was the typical vessel of her fleet in her day; you will note that since then the tonnage—taking these two vessels as a comparison—has been increased sevenfold, the speed practically twofold, and the power fully tenfold. These are the broad, bare facts and they show a sufficient advance, but in detail the differences are even greater. In the *India* the engine-room auxiliaries consisted of one steam donkey pump and one hand pump, while the number of pipes in the machinery space was in all seventy; in the *Rewa* there are thirty-five auxiliary pumps and engines of various kinds, and 960 lengths of piping. The *Rewa* was fitted with hydraulic gear, electric light, refrigerating machinery, all of which were unknown forty years ago.

In the period under consideration, we have come, then, from the simple engine with jet condenser and 25 pounds pressure to the same engine with the surface condenser, then to compound engines with 60 pounds pressure, then to triple-expansion engines with 160 pounds pressure, then to quadruple-expansion engines with from 200 to 220 pounds pressure, and now to turbines, with a possible development of triple or quadruple engines in combination with turbines. The steam turbine, especially for marine purposes, is still in its infancy, although a very sturdy infant it has grown to. Practically all marine turbines, so far, have been of the Parsons' type, but there are others, notably the Curtis, an American invention, for which excellent results are claimed. Mr. Parsons will be entitled to and receive all the honor due to the pioneer who has fought the fight and borne the stress that pioneer work inevitably necessitates. All others must simply be followers in his footsteps and reapers of profit by the good work he has accomplished.

It has frequently been suggested that some inspired engineer would evolve a system of gearing that would be lasting and

reliable, not too noisy, and would not absorb in friction more than say 10 per cent. of power, turbine engines would be capable of application to any speed of vessel and to any size of propeller; you could then have a high-speed turbine and a low-speed propeller, which is the ideal condition for marine propulsion. This condition it is considered may be met in another way, which you will find fully described in a very interesting and capable paper read recently by one of your members, Mr. Durtnall. The system consists of a fast-running turbine driving a small dynamo, the latter again transmitting its electrical power to and driving a large slow-running motor on motors coupled directly to the propeller shaft or shafts. This arrangement does not eliminate the loss caused by the friction of the thrust of the propeller, as is the case in the turbine, and as also, by the way, would not be the case in any system of gear-driven propellers; otherwise one cannot but fear that the cost of this electrical system of propulsion will tell against it. A concrete case was recently put before a firm of electrical engineers who were strong advocates of such a system, but not Mr. Durtnall's; it was proposed to fit it in a ship, duplicate of one already at work with triple engines; the problem was the worst possible from the point of view of the advocates of the new system, but it was very carefully gone into and finally abandoned on account of the very considerable extra cost, and the doubt that existed if this would be met by the promised saving in coal consumption, even if the latter were attained.

There is still Mr. Parson's latest system to test in the adaptation, or rather partial adaptation, of turbines to low-speed vessels; he claims that a considerable economy will be effected by using a higher vacuum than in the case of ordinary machinery, and by interposing between the main exhaust of the ordinary engine and the condenser a turbine driving an auxiliary propeller; that thus he will utilize the final expansion of the steam, which is largely lost in the ordinary engine, due to the smallness of the passages between the low-pressure cylinder and the condenser. There may also in this system be some gain due to the consequent less unequal temperature in the low-

pressure cylinder, but that need not be gone into here. This system will be practically tried in a short time in a vessel for the New Zealand Shipping Company, and also in one now launched for one of the Atlantic lines; the results will be awaited with much interest by all interested in shipping. It is quite clearly understood that the crux of the problem is the relative efficiency of three propellers as compared with two, and this can only be determined by such practical experiments as are going to be made. Land installations have shown that the turbine, as arranged above, will give the economy claimed. Even if the first of the three propeller arrangements does not give the results expected, a modification of the stern in the vicinity of the propellers, and of the propellers themselves, may finally bring them about. In any case, the experiment will be a most interesting one, and the owners who have sanctioned it are entitled to every credit for their enterprize.

As has already been said, the turbine is still in its infancy, and this question of the propellers for turbine engines is one which perplexes all who have studied the matter. The best practical remedy seems to be to peg away at trials, obtain all possible data, and tabulate and analyze such data carefully for future use; by this means in time there will be obtained the power of arriving at the best possible results under any given conditions with at least some fair degree of accuracy. You all know that as the turbine increases in the revolutions which are practicable in marine work its efficiency increases; to obtain high revolutions the propeller sizes must be cut down, but this again decreases their efficiency, and the difficulty has always been and still is to strike the crossing lines of propeller and turbine efficiencies, so as to obtain the best combined result in terms of water used, or in what is equivalent, coal consumed into the speed of the vessel. Coal consumed per shaft horse-power is not a measure of efficiency in the case of turbine-driven vessels; the only basis is as already stated—coal consumption in relation to the speed of the vessel, as is indeed the case with ordinary engines.

You know in a general way that turbines as at present con-

structured are not suitable for low-speed vessels, but the reason why this should be so may not be quite so clear to you. You will best understand the reason perhaps by an illustration, always bearing in mind that the peripheral clearance of the blades and dummies is the important factor in the economical working of turbines. Take two vessels, one with a speed of 22 knots and the other with a speed of 12 knots, each requiring 10,000 horsepower for this speed. Design the propellers in each case on the usual basis for turbine-driven vessels, and make the turbines to correspond. In the case of the 22-knot vessel you will have propellers about 5 feet diameter running at nearly 700 revolutions, and in the 12-knot vessel the corresponding figures will be 13 feet diameter and 110 revolutions. Turbines corresponding to these revolutions will have such clearances that in the case of the slow-running vessel the clearance will be about five times as great as in the quick-running vessel. This clearance and its consequent leakage is the cause of want of economy in turbines of vessels running at slow speeds. A high blade in proportion to the diameter of the rotor, which is not admissible in such vessels, seems to be essential to economical working of turbines. While dealing with clearances, your attention may be called to an ingenious and simple invention recently brought out by the Mr. Parsons, which he calls "tipping the blades." By this system, which will reduce the blades to a minimum section at the very point, it is safe to run turbines with much diminished clearance, and so increase their economy.

The past has seen great changes in our business—what does the future hold for us? Apparently, at least, there is to be no standing still. The combination engine and the turbine-driving propellers by electrical transmission have been already referred to, but there are other systems that have been suggested and advocated with at least some degree of reason; these are internal-combustion engines, gas engines using producer gas, and oil engines. The first and last are used successfully in vessels such as racing launches and craft of small size, but matters are hardly ripe for their introduction on a

large scale; the gas engine has also been given a trial, but the results seem so far to be inconclusive. The extended use of the water-tube boiler in vessels where weight is a serious consideration is one of the problems that must be solved sooner or later. Small and tentative experiments in this direction are even now being made by two enterprising bodies of shipowners, the South-Eastern and Chatham Railway Company, and the Irrawaddy Flotilla Company. If these experiments are successful, considerable modifications will take place in Channel and light-draught vessel practice.—"The Steamship."

COALING AND COAL ECONOMY.

Of the many important arrangements affecting the efficiency of a warship, one of the most difficult satisfactorily to provide for is the reception of the coal into the bunkers, its stowage, and its distribution subsequently to the furnaces. The conditions imposed by ship construction, and warship construction in particular, make the problem the antithesis of that of a shore plant where mechanical devices alone transport the coal from the railway truck to the furnaces. The subdivision of compartments so essential to the safety of a warship makes a number of coal bunkers inevitable, and in a large vessel it is usual for there to be at least twelve bunkers—four lower and eight upper—to each boiler room; each of these bunkers must have means of filling from above, for trimming from the upper to the lower, and to some extent for transference of the coal in a fore-and-aft direction. The number of openings in the decks and bulkheads must be as few and their size as small as possible, and they must be closed by watertight scuttles and doors capable of being worked easily and closed rapidly, in case of collision or damage, from at least one easily accessible position. As a necessary consequence of these conditions, the transfer of coal from a collier or from the dock side to the bunkers is almost entirely a matter of manual labor, while the subsequent transference from bunkers to furnaces is exclusively so.

The recent increases in speed of warships and the consequent increases in power involve correspondingly greater coal consumption, and unless the speed of coaling can be augmented more time must be spent in this arduous and uncomfortable operation. In our issue of July 10th we published a report of Admiral Evans, of the United States Navy, on the fleet under his command, containing some interesting observations on the question of coaling. He considers the subject of such importance as to merit the most careful consideration, from the operation of bagging the coal to its final trimming in the bunkers. A complete review of the subject shoulld include the design of colliers to make them fit the average battleship, so that the greatest number of men and hoists may work at the same time. The problem is, as Admiral Evans points out, one of great tactical importance, for a vessel during the time of coaling is not an effective unit of a fleet. In our own Navy there have been many remarkable coaling performances, and much emulation exists in the ships of the various fleets to show a smart coaling record. The time taken, as shown by the returns, does not, however, represent the time during which the ship is out of action. There is the preliminary work of rigging coal chutes, where, as in a number of cases, they are portable, and these same chutes have afterwards to be unshipped and stowed. Many of these impedimenta could not be left in place without interfering with communication along the decks, and their removal is therefore necessary before the vessel resumes her character as an efficient fighting machine. There is, further, a good deal of trimming in the bunkers to be finished after the last bag has been hoisted on board, and this trimming must all be completed before the last of the armored scuttles can be closed.

As a moderate estimate, a battleship requiring to refill bunkers may be considered *hors de combat* for twenty-four hours, and for at least half this time to be incapable of giving chase at full speed, while if the coaling appliances on the ship or collier are indifferent these times may be greatly exceeded. History repeats itself, and it is quite possible that under mod-

ern conditions we may see a repetition of the chase which Nelson made after Villeneuve. Absence of definite information due mainly to Nelson's lack of frigates made this pursuit abortive. In the modern instance, should it occur, coal endurance and the ability or otherwise to coal with rapidity will be the determining factors. The tactical advantage of rapid coaling which Admiral Evans emphasizes is thus very great, but except in points of detail it is difficult to see how any advance is to be made. The coal has to be bagged in the hold of the collier and trimmed into the bunkers, and while these operations are essentially manual, quickness of coaling is mainly a matter of physical endurance on the one hand and organization in the routine of shooting the coal into the various bunkers so as to avoid blocking the chutes on the other. The intermediate operation of hoisting on board can in most cases be done much more quickly by the colliers' winches than the bags can be filled or the bunkers trimmed.

As we cannot reasonably expect any great advance to be made in the speed of coaling over these obtaining at present, the questions of bunker capacity and economy of the propelling and auxiliary machinery become of additional importance. In our most recent ships bunker capacity has been largely increased with the disadvantage pointed out by Sir William White, that the sinkage from normal to deep draught has been also increased, a rather serious disadvantage affecting the efficiency of the armor belt, but an inevitable part of the price which has to be paid for increased speed. Another factor in this problem is the use of oil fuel, the tactical advantage of which was demonstrated in the maneuvers of two years ago when the fleet under Sir William May using oil fuel easily evaded the pursuing fleet. The use of the double-bottom compartments for the storage of liquid fuel has undoubtedly contributed to the solution of the problem of obtaining higher speeds without sacrifice of radius of action.

The question of rapid coaling, as we have shown, mainly depends upon the human element; the question of bunker capacity is one of construction which does not permit of much

variation in treatment, and it is to the matter of economy of fuel consumption that all such discussions must inevitably lead. The vessel with the lowest coal consumption is invariably the best steamer; she will "get there" quicker and take less time to refill her bunkers than her less economical sisters. To refer again to Admiral Evans' luminous report, he says the variable performance of the ships of this fleet would indicate that this is as much a question of economy in the design of the engines and boilers as in the actual capacity of the bunkers, and in the succeeding paragraph he refers somewhat caustically to the performance of one of his ships which has no economical speed and burns over thirty tons of coal a day in port. Coaling a vessel with such an appetite as this must, indeed, be a Sisyphean task.

It would almost appear that we have reached a limit in the economy of the main propelling machinery of warships, as the coal per indicated horsepower has been practically stationary in the last decade, while owing to the multiplication of power-driven mechanical appliances on board, the consumption of coal for auxiliary purposes has sensibly increased. In spite of the cheery optimism of some of the advocates of the internal-combustion engine, it is to be feared that the prospect of reducing the coal bill of the main engines by gas-engine propulsion is still remote; but, on the other hand, there does not appear to be any great difficulty in the way of reducing the expenditure of fuel for auxiliary purposes by employing oil or gas motors, and, in fact, a start in this direction has already been made in our own Navy. The importance of economy of coal for auxiliary purposes is not often realized. In the hypothetical reproduction of the famous incident to which we have previously referred, the modern Nelson will be watching with dwindling bunkers while the modern Villeneuve is waiting his opportunity to escape, and when at length the chance arrives, Nelson may find that he has not coal enough left to give chase at full speed. A vessel so uneconomical as that mentioned in the report quoted will empty her bunkers in two months without having moved her screws, and she would be almost useless at some distance

from a coaling base. To be able to coal quickly when required is good, but to be able by superior economy to outstay a rival is better, and if the former merits careful study, the question of the economy of main and auxiliary machinery deserves to be made the subject of exhaustive research.—"The Engineer."

HEAT AND WORK.

The presidential address delivered in Section G by Mr. Dugald Clerk was a distinguishing feature in the proceedings of the British Association in Dublin. Mr. Clerk's reputation as an engineer first, and a physicist afterwards, is so high that a good deal was expected, and he has not disappointed expectation. It is an excellent thing that the young men of the present generation should have the history of that section of thermodynamics with which the industrial world is most concerned clearly stated. The precise nature of the achievements of such men as Carnot, Clausius, Rankine, Thomson, Joule, Regnault, and many others named by Mr. Dugald Clerk are, we fear, often forgoten by too many of the present generation. The address of the President of Section G will do much to place the great physicists of the last century in their proper position.

We shall not attempt to follow Mr. Dugald Clerk into details. We shall confine our attention to one point only, on which, indeed, Mr. Dugald Clerk based most of his address, namely, the conversion of heat into work. It will, we fear, be news to many students that the most eminent authorities of their day did not believe that as work was done heat disappeared. The theory which held possession of the scientific world for many years was that heat was an entity, called for convenience "phlogiston." Mr. Dugald Clerk states the nature of this belief in detail; and he goes on to show how slowly more accurate notions replaced a very convenient theory. In this connection, however, he has not done full justice to such men as Count Rumford, who by a classical experiment made by boring cannon, showed that heat was produced by the work

done by the horses who turned the boring tool. Again, although it is true that Tyndall and Donkin lived after the period covered by his address, he might have pointed out that the former, by his lectures and by his books, did much to establish and popularize the theory that heat is a mode of motion—words far more pregnant than they appear to be at first sight. To the late Bryan Donkin, Jr., belongs, again, the credit of being the first to show in actual factory practice the disappearance of heat into work in a steam engine. This he did by measuring the rise of temperature and the volume of water required to condense a known weight of steam passing through a compound beam engine driving the tools in the Bermondsey works of his firm. The condensing water was passed through a notch-board in a quieting tank, and every effort was made to get accurate results. A difficulty lay in the fact that there are six recognized coefficients for discharge over weirs, none of which agree. The differences in result are, however, small; and although an element of uncertainty existed, Donkin was able to prepare balance sheets which not only proved beyond dispute that heat was converted into work, but that it was possible to express the efficiencies of steam engines in entirely new terms. In the present day all this is familiar even to the first year's student. It would be a pity if credit was not awarded to the man who first showed how the facts could be utilized by the engine builder and the steam user.

Mr. Dugald Clerk had a good deal to say about specific heat. Within the last few years there has been doubt expressed as to the accuracy of much that has previously been accepted as absolutely true. Facts come to light and acquire an importance because they are apparently not consistent with other facts previously ascertained. A revision of theory is no doubt going on which may prove not a little helpful to the practical designers and makers of heat motors. Not the least remarkable feature of present-day thought is the possible revival of the theory that heat is a material entity. Not indeed a ponderable fluid, but a condition of a portion of the ether. Such a view has been more than hinted at by such men as

Lodge and Le Bon. Whatever may be said of this, it at all events is clear that so long as the true nature of heat is unknown, various theories will be advanced whose importance will be measured by the reputation of the men putting them forward. It seems to us that before any great step can be made in formulating a theory of heat engines, it will be necessary to settle something about the way in which heat is converted into work. Up to the present moment the words are used in a very restricted sense. There is no accurate concept formed of what goes on. We say that heat is a mode of motion. The words do not explain what heat is; they only assert that when a body is heated its particles are put into motion, and that when it is cooled they lose motion. Are the constituent molecules wholly inert, moved backwards and forwards by "heat," as the shingle on the sea shore is moved by the waves? Or is the motion a something inherent in the gas? The electrical theory of the present day only moves our puzzle one step backwards. All that can be said at the moment is that the true definition of heat is that it is a mode of motion of the ether, made manifest to us by molecular vibrations of matter.

Leaving such speculations on one side, we may at least say that since the days of Clerk-Maxwell it has been fully accepted that the pressure of a gas is due to the collision of its molecules with the surface of the containing vessel. This being so, it is easy to see how the energy of, let us say, steam behind a piston is converted from one form of work into another. What is true of a multitude of molecules is true of one. Let us suppose an engine cylinder in which the face of the piston and the cylinder cover are absolutely hard, and that inside we have a ball perfectly elastic, bounding backwards and forwards between the piston and the cover; there is no loss of energy in the ball, no conversion of heat into work. If, however, the piston moves, the recoil from its face will be less rapid than the impact, and the repetition of the process will result in a continual loss of motion by the ball. If the operation could be carried far enough the ball would entirely lose its motion.

Absolute zero would be reached. To ascertain the energy in one ball would not be difficult. To ascertain that in countless myriads of them is not so easy. The "specific heat" of a gas really means the measure of the energy which is represented by the motion of its particles. The method of the conversion of the work in a pound of steam into the work done by the rotation of a crank shaft is obvious enough. It is in effect that of a Pelton wheel. It is not until we come to explain how the molecules are put in motion that we are in difficulties. It is here, of course, that the ether-wave theory comes in, and that is far from complete. Just as there are waves of "dark" light, so there are "heat" waves which are absolutely cold. Pure radiant "heat" waves have no temperature. Interstitial space is at zero. It is conceivable that ice might be placed near the sun without dissolving. A lens of ice may be made to act as a "burning glass" without itself melting. It is the collision of the waves with solid bodies that produces what we term heat. When we come to examine the old-time notion that heat was a separate fluid, we can easily see that although the theory was incompatible with certain facts, yet that it is by no means certain that if we leave out the word "fluid," and speak only of a separate entity, we shall not be nearer the most recent views of the physicist than we shall be if we confine our definition of heat to "a mode of motion." Mr. Dugald Clerk has given us the last word on the subject from the engineer's point of view: but the world does not stand still, and the research and inquiry which he advocates may have results which will modify our views on thermodynamics in more ways than one. It is at least certain that so far no rational theory of the production of energy by the explosion of gases has been formulated, if we exclude that of Dr. Le Bon as untenable.—"The Engineer."

WATER HAMMER.

The engineers who have not heard of water hammer must be very few; the number of those who understand what it is is still fewer. Stop valves and cast-iron steam pipes are burst

now and then with more or less violence. When there is no other way of accounting for the disaster, it is put down to water hammer. The theory of water hammer is quite simple. A quantity of water accumulates in a steam pipe. The stop valve is opened to start the engine. The rushing steam picks up the water and drives it with such violence against the partially-closed stop valve, or a bend in the pipe, or some other obstruction, that the metal yields as it would to the blow of a heavy sledge hammer.

Such an explanation seems quite obvious—a theory to be accepted without question as final. Unfortunately this is not all. The explanation leaves some questions unanswered—certain problems unsolved. For example, why should there be a a violent rush of steam when the stop valve is scarcely opened? How does the steam pick the water up off the bottom of a steam pipe at one moment and flow quietly over it at another moment? Has anyone ever attempted to ascertain the force of a blow which can be given by the water in, say, a 6-inch steam pipe? Model tests with glass tubes have been carried out by Mr. Stromeyer which truly show a water-hammer action; but these are qualitative experiments, so to speak, not quantitative. No numerical expressions can be deduced from them. In practice the means usually seem to be inadequate to the end. It would appear that there is not water enough or velocity enough to smash up pipes and valve chests in the way in which they undoubtedly are smashed.

A recent Board of Trade report presents us with an interesting example of water-hammer problems. We have some facts which are not easily explained, and, as a matter of fact, no attempt has been made to explain them by Messrs. Longstaffe and Gray, the Commissioners who have investigated the case and reported on it. These gentlemen admit that the phenomena of water hammer are "not all even yet known to engineers," and it will, we think, be seen before we have done that they have good ground for this somewhat apologetic statement. The facts are easily stated. A 3-inch sluice stop valve burst about 12·35 P. M. on the 28th February, in the New

Foundry Department of the Stanton Ironworks Company, Limited, Stanton, Ilkeston. James Riley, laborer, and Christopher Shaw, fitter, were killed. Thomas Smith, assistant foreman fitter, Edward Martin, Frederick A. Tansley and John Keeling, fitters, and Herbert Whatley, engine driver, were seriously injured. The valve was made by Messrs. Glenfield & Kennedy, and it will save time to state here at once that there was no flaw or defect in the valve; that the cast iron was of excellent quality, and that two years ago the valve had been tested, when new, up to a pressure of about 400 pounds. The boiler pressure under which it worked was about 160 pounds. Two engines are on the premises of the Stanton Ironworks—one the "regular shop engine," another a duplicate or stand-by engine. The regular engine was going to be laid by for repairs, and the duplicate engine was started. Then the explosion took place. The steam which the company requires for its engines is supplied by seven Lancashire boilers worked at a pressure of 160 pounds. That steam passes first through a range of pipes 9 inches in diameter, and from that range is carried through another range of cast-iron pipes 6 inches in diameter. The last mentioned range, in its turn, communicates with another range of pipes 4 inches in diameter, and it was upon this range of 4-inch pipes that the valve in question was placed. Upon that range of pipes there is a drain valve for the purpose of carrying off from them, and clearing them of, such condensation water as is created. The open end of the drain pipe which drains these 4-inch pipes is about 30 feet distant from the valve, and discharges into an old disused flywheel pit. The stop valve is placed with the spindle horizontal. A species of expansion loop is formed on the steam pipe, the level of which last is below that of the stop valve. The descending elbow of the loop is a couple of feet long, and no means of draining it exist. As soon as the valve is opened any water in the elbow will pass into the engine, but the quantity which can collect is very small, and lying quietly on the valve, can do no harm. Now the main steam pipe is very long, and condensed steam would no doubt accumulate in the 4-inch sec-

tions if the drain cock was closed. The men in charge are said by the Commissioners to have been highly intelligent, thorougly understanding all about the engine and the piping, and they did what they had often done before—they opened the drain cock, and one of them descended into the wheel pit and satisfied himself that water and steam were coming out before he attempted to open the stop valve. So far as was known there was no water in the 4-inch pipe at that time; but the 4-inch pipe was joined by a tapered reducing piece to the 6-inch pipe, and it appears to have been possible for water to have "ponded" on the bottom of the 6-inch pipe until it rose high enough to flow over into the 4-inch section. The maximum depth could only have been 1 inch. How far back in the 4-inch pipe the ponding could have extended we have no evidence to show.

Be this as it may, the Commissioners hold that this water was picked up by the steam, flung violently through thirty feet or so of 4-inch pipe with five sharp bends in it, ultimately striking the valve chest with such force that it burst it. We do not say that this did not happen, because we do not know whether it did or not; but we do say that it was a curious and unlikely performance if it did. It is quite clear that there must have been a very violent rush of steam to project the water in this way. Let us see whether the conditions were likely to set up this rush or not.

The Report is far from lucid; indeed, in certain places it is hard to understand. There were two drain cocks, one on the 6-inch and the other on the 4-inch pipe, and both these were, we are told, open for about an hour before the explosion took place; but nothing is said as to the inclination of the steam pipe, and there is no means of knowing whether "pocketing" took place or not. In the elbow before referred to right over the stop valve lay, it is supposed, about half a gallon of water, all the elbow would hold. It appears that from the first—that is to say, for at least an hour—the boiler stop valves had been open, and the steam pipe was therefore charged with steam. In fact, it seems as though the regular shop engine which was

nearest to the boilers had been at work all the morning, and was only stopped when the duplicate engine was to be started. The valve wheel was moved by the foreman fitter Smith, who was badly scalded. He turned the wheel about an inch, opening the valve a very little, while four men barred the engine round. Smith very cautiously opened the sluice valve a little further, and then the valve chest burst. The engine, be it observed, had been drained and warmed up just before, so that no rapid condensation of steam could have taken place. Nor is it clear that there was any water in the valve chest or elbow. Even if the stop valve had been opened wide suddenly, as the engine could not take the steam, for it had not started, it is difficult to understand in what way a rush of steam might have been set up.

It is quite clear from the Report that the Commissioners found themselves in such a position that they must say that the smash was due to water hammer, or else admit that they were unable to furnish any explanation, for they write all through, with commendable caution, "we think;" and they further protect themselves by stating twice that engineers do not understand the phenomena of water hammer. As it was admitted that the three-quarters of a gallon lying on the stop valve could do no particular harm, even if it was there, they had to find water elsewhere, and this they did, as we have shown, in the 6-inch pipe. But the water could not have been there if the drain cock was open. To get over this difficulty they say that they do not believe the direct and positive evidence of two witnesses that the cocks were open, maintaining that the men were mistaken. The Commissioners, be it remembered, admit all the time that these men were highly intelligent, truthful, straightforward and competent. Our readers must form their own opinion as to the value of the assumption that the drains were really shut. We ourselves see no reason for rejecting what was really first-class evidence.

We have no explanation to offer. A most searching inquiry results, we think in leaving the explosion unexplained. The circumstances were sufficiently startling. Here we have an en-

gine started as it had been started many times before. It was in the hands of men who were, it is admitted, above the ordinary run of fitters and engine drivers. Every legitimate precaution appears to have been taken. The Commissioners have no fault to find with any one. On the contrary, they have nothing but praise for all concerned. The arrangement of the steam pipes they say was practically satisfactory. They cannot suggest an improvement. The precautions for draining the pipes were all that could be desired. We reserve for the last their explanation of what took place. We give their own words: "When the steam was admitted to the engine by Smith, we think that the water standing in the 6-inch pipe was driven and forced against the column of water standing immediately above the valve, and that the 'water hammer' thus produced fractured it." A moment's reflection ought to have been sufficient to show that before any rush of steam could have taken place, the water on the stop valve must have passed into the engine. There is no scrap of evidence that there was any water there; and, lastly, it may be pointed out, that the projection of a "lump" of water at a high velocity round five nearly right-angled bends appears to be a physical impossibility. Water-hammer action almost always means a straightforward blow, smashing the first obstacle, which in this case was a bend. Velocity would have been lost at each bend—a fact which the Commissioners seem to have overlooked.—"The Engineer."

THE CORROSION AND DECAY ON METALS.

Lecture by MR. J. T. MILTON, Member of Council Institute of Marine Engineers, at the Franco-British Exhibition, September 5, 1908.

The subject of the lecture tonight is of such importance, both to the constructive engineer and also to the engineer whose business it is to attend to the maintenance of the structures placed in his charge, that no apology is needed in bringing before the Institute of Marine Engineers. To the constructor because he has to provide an excess of material in his design to

allow for an inevitable deterioration which he knows will take place; and thus at the outset, and right through the useful life of the structure he creates, it is handicapped by having to carry more weight than would be necessary if he could ensure that no weakening by decay or corrosion would occur. To the engineer in charge because his every-day work includes the taking of precautions against the failure of each one of a large number of small details, the failure of any one of which, owing to the interdependence of so many parts of the mechanism, may produce serious consequences out of all proportion to the seeming importance of the detail in question.

By far the most important material used in engineering structures is iron in its various forms of cast iron, wrought iron and mild steel, and unfortunately iron is one of the metals most liable to decay or corrosion. The corrosion of iron is almost but not invariably due to its affinity for oxygen, and the consequent formation of oxide or rust. Cases of decay of cast iron, however, occur, to which reference will be made, in which the formation of rust does not appear to be the sole cause of the trouble, but rather the formation of some soluble compound which is washed away or dissipated by the corrosive influence itself.

Although the formation of rust is of such a common occurrence, there is not by any means a concurrence of opinion as to the precise way in which rusting takes place. The presence of water seems to be essential, but water by itself will not rust iron. When bright iron is immersed in pure water which has been freed from dissolved air it remains bright for an indefinite period, but, given the access of air or oxygen in solution in the water, rusting almost immediately sets in. It is stated that the action of oxygen and water is comparatively slow except there is also the presence of a small amount of free CO_2, and that when this is present the rusting is much more rapid. It is on this account that in cases where oxygenated water has necessarily to be kept in contact with iron the presence of a little caustic lime in the water is found to be preservative, the lime (calcic oxide) has a strong affinity for CO_2, forming

calcic carbonate, and prevents the gas from remaining in the water.

In the cases of many metals which are readily oxidizable (lead is an example) it is found that when the outer surface of the metal has combined with oxygen the thin film of oxide so formed prevents the access of further oxygen to the metal and so stops further corrosion. In the case of iron, however, this is not the case. It is unfortunately true that iron once rusted corrodes more quickly than clean iron when exposed either to moisture with access of air or oxygen, or when exposed to moist air. The reason for this is obscure; but it has been said that the oxide of iron formed (Fe_2O_2) will under certain conditions, either of temperature or moisure or both, occlude or separate out and absorb from the air an excess of oxygen, whilst in other conditions of temperature, etc., it gives up the oxygen so occluded. Evidently if this is the case, when the occluding conditions occur the coating of oxide can most readily obtain the oxygen from the side nearest the air, whilst when the reverse conditions occur it can equally readily divest itself from the excess of oxygen by yielding up some of it to the contiguous iron on one side, as by giving it up to the air on the other side of the film. Whilst this is a possible reason, it may not be the only reason for the continuous oxidation of the iron covered by a film of oxide. It may be that the oxide itself is not an absolutely coherent solid mass such as the ordinary senses imagine metals to be, but it may really be of a porous structure, with openings or vacuities sufficiently large for molecules of oxygen to freely penetrate them and so obtain access to the iron underneath, or even sufficiently porous to contain sufficient moisture to support an electrolytic action, to which reference will presently be made. However, the important fact remains that a coating of rust once formed on iron is no protection whatever against further oxidation, but the reverse, so in all cases where rust has once formed it is best to remove it as soon as possible. Evidently the best way to prevent iron from oxidation is to prevent the corrosive influences from coming into contact with it, and for this purpose,

whenever the use of the structure will permit it the surface should be covered with something to keep air and moisture away from it. The most usual protection is paint, whilst cement, asphalt and galvanizing are also employed with more or less success.

The subject of paint is one very well worth study by engineers, but is too complex to be dealt with in the present lecture beyond making the statement that an ideal paint is one which can be easily spread on the iron, will not flake off, and will quickly dry into a hard coherent coating so continuous or free from porosity that it will not permit of the passage of moisture or of air through it. Such a paint has not yet been found, although many good paints when properly put on do protect in a very marked degree the metal under them from corrosive influences.

Portland cement is usually employed only for parts where water is always present, and experience with the inner surfaces of the bottoms of iron and steel ships shows that where it has been put on of sufficient thickness to endure durability it effectually prevents corrosion both when applied originally to the bare iron and to iron previously coated with good paint. The thin coating of "cement wash" applied to parts which cannot be cemented in the ordinary way, however, cannot have the same good character given to it, as we see by the severe wasting which occurs to the floors and reverse frames, tank tops, etc., of vessels which have been treated in this way whilst building.

Galvanizing is a process of covering the iron with a thin film of zinc, and is very efficient for a time in most cases in which it can be applied, and where only atmospheric influences have to be resisted; but after a time it, the zinc, becomes wasted and its preservative effect is lost, and then as the iron cannot be again galvanized the further preservation must be attempted by means of paint.

At first protection is afforded simply because the first coating of oxide which the zinc surface acquires protects the metal from further oxidation, but this in time wears off, more oxide

forms, and at last the zinc coating, in spots, becomes completely worn through, leaving the iron surface exposed. The preservative effect, however, has by no means been lost, and the iron in the exposed parts is still preserved by the zinc remaining on other parts through what is called galvanic action; and not until the zinc has practically disappeared from the whole surface does the now exposed iron begin to corrode.

If two dissimilar metals are immersed in a corrosive liquid, or exposed to a corrosive atmosphere which will act on both of them, so long as they are not brought into electric contact each is acted upon in precisely the same manner as if the other was not present; but if the two metals are brought into electric union, then the whole of the corrosive influence is transferred to one of the metals, the other being protected; at the same time an electric current is set up which proceeds from the most corrodible metal through the liquid to the other metal, and thence through the electric path or connection back to the most corrodible metal. In the case of a plate of zinc and one of iron being both immersed, say in salt water and electrically connected the iron will not corrode, but the zinc will. In common language, the iron is protected at the expense of the zinc. This is the principle upon which depends the preservation of boilers by means of zinc plates placed in them. In a worn place of galvanized iron there is electrical communication between the iron and the remaining zinc, and so the iron is preserved at the expense of the zinc so long as any remains.

At the same time let it be noted that there is a galvanic current produced flowing through the electric connection from the protected metal to the more corrodible metal. The energy of this current is proportional to the chemical action, which is represented by the corrosion.

Although we have taken iron and zinc as our illustration, the same results hold with any two dissimilar metals, one at least of which is acted on by the corrosive fluid, and we constantly meet with cases in which dissimilar metals placed in electric contact at one part, and subject to the same corrosive action at other parts, set up a galvanic action which results in

the protection of one of the metals at the expense of the other. Even when two metals so much alike in chemical and physical properties as wrought iron and mild steel are used together, the slight differences between them lead to some galvanic action when they are exposed to suitable conditions, and usually the wrought iron is then preserved at the expense of the mild steel.

Now let us take a glass vessel and put in it a liquid of slight corrosive power,* and insert in it two plates, one of iron, the other of copper, and, so long as there is no electric contact, both plates are acted upon in the manner peculiar to themselves and to the corrosive liquid; but connect the plates, say by a wire, and we have at once a current set up as indicated by the arrows, and at the same time the iron plate is more actively corroded than before, whilst the copper is preserved. If now instead of I and C being both immersed in the same liquid, which it will have been observed conducts the current from I to C, they were immersed in separate cells which have no electric conductivity between them, then no current is set up and no protection is afforded to I by Z even although they are connected by the wire. For the galvanic action to take place, therefore, it is essential that the current should flow from I into the liquid and from the liquid into C. This can be arranged by immersing a connection B in both cells, and we then have the complete galvanic action produced. Note that the corrosion takes place where the current leaves I to go into the corrosive liquid. Now instead of the right hand cell let us suppose we have a source of elctricity supplied altogether distinct from that obtained through the plate C, so that we get a current entering I of the same intensity as before, and the same intensity of current consequently leaving I into the liquid, I will then be under precisely the same conditions as before in being exposed to a corrosive medium and in having a current passing through it, and it will be found that it cor-

* In these experiments the liquid was water with one part of nitric acid to two hundred of water, and a little common salt to increase its electric conductivity, and a small quantity of ferrocyanide of potassium. The latter gives an intense blue coloration when there is a trace of iron present.

rodes exactly as before. We see, then, that one condition to ensure corrosion is that a metal shall be exposed to a corrosive influence, and that a current shall flow *out* of the metal into the corrosive liquid. This action is the cause of much trouble due to the wasting of water and gas pipes, etc., in the earth by currents due to leakages from electric mains, and from the return paths of electric rails in tramways, etc. We must return to this question of electrolysis by and by when dealing with the deposition of scale on screw shafts, but at the present it is enough for us to note that all that is required to set up corrosion in a piece of metal is that a current, produced somehow, either by the corrosive influence itself or by some altogether extraneous means, does leave the metal where it is in contact with a corrosive element, and that then the amount of corrosion so produced is proportional to the amount of the current and to the time during which it acts. It is evident that if the same current is distributed over a large surface so that its intensity per unit of area is small the corrosive effect or loss of weight of the metal per unit of area will be less than if the same current is concentrated on a smaller area. Hence we see that if the surface of the metal is for any reason generally obstructive to the flow of the current, but at the same time certain parts of it are less so than others, so that these parts conduct more than their own share of the current, then these parts will receive more than the average of the resulting corrosion, or in other words they will become "pitted." It is this which leads to severe pitting in places where paint or protective scale has been accidentally locally removed, and it points to the importance where scaling has to be done of having it thoroughly done, otherwise the freshly-cleaned parts will receive all the corrosive influence which ought to have been distributed over a larger area.

We will now take two cells and a battery, and we will arrange matters so that in one cell the current from the battery enters the iron plate to be corroded, flows through the liquid to the other pole, which we will make of carbon, which is an incorrodible material, thence to a similar carbon pole in the second cell, then through the liquid to another iron plate, and thence

back to the battery We shall find that in the first cell, as before, corrosion occurs on the plate where the current leaves the plate to enter the liquid, but in the second cell where the current enters the metal from the liquid no corrosion whatever occurs, even although there is precisely the same current passing through both cells.

In the next experiment we will make the current concentrate a more than usual proportion on one particular point, and in this case we shall find the iron in a short time will be pitted right through.

Two instances only will be mentioned of sources of current affecting corrosion on board ship: First, electric machinery; second, the differences of temperature to which different parts of the structure are subjected. Electric leads are constructed on two systems, the single wire with hull return, and the double wire. In the single wire the current leaves one pole of the dynamo and is distributed as required by a system of branching mains. From the lights, etc., it is returned to the structure of the ship, and thence to the other pole of the dynamo. The conductivity of the steel hull of the ship is so enormous that it seems at first sight that absolutely no current could leave it between the points where it enters and the connection to the dynamo pole; but where there are several ways open for a current to traverse, it is known that it will divide itself between all of them, the portion flowing through each path being inversely proportional to the resistance of that path, so that some current, however slight, must flow through every possible path between the electric-light connection and the dynamo pole; and if one such path lies along a way where the current will leave a corrodible metal to enter a corrosive medium, some corrosion will take place there. With a leaky cable the leak similarly distributes itself over every possible path to the hull of the ship, and it may be that in some cases it finds a short path through some pipes or fittings which it corrodes, and which otherwise would be unaffected. In the double-wire system a defect in one cable only will not leak electricity unless there is a means for the electricity to return

to the other cable. If there are defects in both cables, then the leakage from one to the other divides itself between every possible course. In this way, with either system, we get what engineers on board ship term "stray currents," very difficult to detect, but very serious in the long run, not so much on account of the loss of power of electric plant they represent, but because of their sure though slow action in effecting the corrosion of some part of the vessel.

It is, however, perhaps from the differences of temperature of different parts of the vessel that we have the most serious results ensue on board steam vessels. It is a well-known experimental fact that given two pieces of the same kind of metal electrically connected, but at different temperatures, the warmest will always be electro positive to the other, and if they both are in the same corrosive medium a current will flow from one to the other. It is in the double bottoms under the boilers that this finds the greatest illustration. Here we have all the conditions for corrosion. The upper part is heated by the boilers, the lower plates are kept cold by the sea. They are in communication by the floors, etc., and are surrounded either by sea water when the tanks are full, or by moist air when they are so-called empty. A current is set up and corrosion occurs. The remedy appears first to as much as possible prevent the differences of temperature by preventing the heat of the boiler from reaching the ship structure, and second by ensuring that there is no corrosive medium either of sea water or moist air in these spaces. This can only be done by ensuring that the spaces are kept absolutely dry. Thirdly, by paying particular attention to keeping these parts thoroughly protected by paint inside, and by paint or other means outside. These points are given much more attention to now than formerly, but they are so very important that they will bear repeating and emphasizing.

Another part of the vessel to which the same differences of temperature must affect the structure and set up currents is in way of refrigerating spaces. Here, however, the reverse conditions occur. The parts of the vessel hidden from view be-

hind the insulation are kept cooler than normal, and so they tend to be preserved instead of corroded; moreover, they are kept dry instead of moist, and on these accounts they do not corrode or give undue trouble or anxiety. The same influence of differences of temperature can often be seen in boilers. For instance, the shell of a donkey boiler, if corroded at all, will be found to be corroded on the side nearest the main boiler chimney, and to be free from corrosion on the other side.

So far we have spoken of corrosion as due to the action of a corrosive liquid or medium on the metal either under normal conditions, or intensified by electric current so arranged that the current leaves the metal to enter the corroding medium. Now for a moment consider the reverse action. Turning to our original experiment, we saw that if both the plates were by themselves corrodible in the liquid, when electric contact was made the one which was least corrodible was protected by the arrangement, and we also saw that it was not necessary to have two dissimilar metals to make the one corrode; a current, however generated, was sufficient to affect the same purpose, provided it was made to leave the metal. Now let us reverse the direction of the current, and we shall find that, provided it was made to enter the metal from the liquid, corrosion is stopped. This experiment shows that electric currents may be made to protect as well as to corrode.

So far our remarks have all been made to apply to the case of a metal of homogeneous structure, that is to say of which each and every point has the same physical properties. Let us see what will happen if the metal is not homogeneous. No metals are absolutely pure. How are the various impurities which exist in the metals actually distributed through the mass? When two or more elementary substances are mixed together we produce either one of three different kinds of arrangement of the individual particles. We may have first what is called a mechanical mixture, in which each individual particle of each substance has retained its own individuality and is merely mixed up with the other particles, and if we had patience enough we could again separate each from each. As an in-

stance, consider a mass of iron and brass filings mixed together as intimately as possible. Each particle of iron remains iron distinct from all the particles of brass, and the use of a magnet will be sufficient to again separate all the iron from the mixture.

Next we may have a chemical combination; definite numbers of atoms of each component unite together and form an altogether different substance with physical properties from either of the component parts. A chemical combination has the property that each part of it, however minute, contains precisely the same proportion of each constituent as every other part, whereas in a mechanical mixture we may have very considerable variations of the different constituents when we closely examine very minute parts of it.

Thirdly we have what is called a solution. As an example take a solution of salt in water. Here we have, when carefully examined, the same proportion of salt and water in each and every part, but the proportions, instead of being definite as they are in a chemical compound, may be anything ranging from the very smallest amount of the dissolved substance up to that particular amount which saturates the solution. (Under certain peculiar cricumstances it is possible in some cases to have a supersaturated solution, but this is always a condition of unstable equilibrium.)

We not only may have liquid solutions, but the same equable distribution of the one substance within the other, if in the solid state is also called a solution, but in this case it is generally called a solid solution. The three states of distribution of different elementary substances then are: (1) Chemical compounds distinguished by every part, however minute, being composed of precisely the same definite atomic proportions, and consequently being homogeneous; (2) solutions in which each and every part also is composed of precisely the same proportions, and the substance is, therefore, still homogeneous; but these are not atomic proportions and may be varied indefinitely below the maximum or saturated condition of any one of the constituents; and (3) mechanical mixtures in which, when

minutely viewed, the substance is not homogeneous, small measurable portions being composed wholly of one constituent and others of other constituents.

When we come to closely examine metals we find in them all three forms of these arrangements. As an example of a chemical compound let us take a yellow brass composed of about two atomic parts of copper to one of zinc. If the copper is first melted in one crucible and the zinc is then added, either by having been separately melted and poured into the copper, or even by being put as a solid into the molten copper, combination takes place with the evolution of a considerable amount of heat, and the resulting metal is altogether different from either of its constituents. It is perhaps not so ductile as the copper, but is immensely more so than the zinc. It is a different color from either of them and is stronger than either. Whereas copper can be worked either hot or cold, this cannot be worked hot—in fact it is a different metal altogether. If instead of taking two parts of copper to one of zinc we take about equal atomic quantities, and treat them in the same way, we obtain another chemical compound. Like the other it is yellow, harder than copper, and possesses considerable ductility, and is altogether different in its physical qualities from either copper or zinc. It is a true chemical compound.

Now instead of taking either of the proportions named, suppose we take some intermediate proportion, say 60 per cent. copper and 40 per cent. zinc, which is the composition of the alloy so well known under the name of "Muntz Metal." We still, on mixing the molten metals, obtain chemical action with the evolution of heat, but what really takes place is that we get actually a mixture of the two chemical compounds Cu_2Zn and CuZn. There is not enough zinc in the mixture to make all CuZn, nor is there enough copper to make all Cu_2Zn, so when equilibrium is obtained there is a mixture of these two constituents in such a proportion that every atom of copper and every atom of zinc is combined in one or other of these proportions. While the resulting metal is fluid each of the components is mutually dissolved in the other and we have a

homogeneous solution of CuZn in Cu_2Zn, or of Cu_2Zn in CuZn, whichever way we choose to view the matter. If now the mass can be cooled very suddenly we are able to retain the two constituents in their homogeneous solution, and we have a homogeneous solid solution as a result. If, however, the cooling is allowed to take place more slowly, then each of these metals separates out from the other, and the result is that we have a mechanical mixture of the two constituents. Here then we have in one alloy, "Muntz Metal," an exemplification of two different chemical compounds, each differing from the constituent metals, of solid solution of one of them in the other, and of a mechanical mixture of the two chemical compounds, the condition of solid solution or mechanical mixture being solely in this case due to the conditions of cooling from a high to ordinary temperatures. Actually the separation of the two constituents takes place at a temperature lower than that of solidification, so that here we have a wonderful instance of the transference of solid metallic molecules through the solid occurring during the "segregation," as it is called, of the different constituents. This is a subject which has not been fully investigated and is outside the scope of the present lecture, but some illustrations will be given to show what actually takes place, as the mechanical mixture or separation of these two metals has a distinct bearing on our subject.

The actual mixture of the two constituents is shown by the microscope. Both the compounds are of the same yellow color. When the metal is cut it appears to the eye as homogeneous, and when it is carefully polished and microscopically examined it still presents the appearance of a yellow mirror-like surface with no markings whatever on it. Let it now be lightly etched with acid, and we find definite marking on it, certain portions of the surface become darkened whilst others remain bright. What has happened is that the acid has really commenced to dissolve the surface of the CuZn portions, leaving that of the Cu_2Zn untouched. How we recognize each constituent which we see is by taking several samples of alloy varying in composition from CuZn to Cu_2Zn; treating them all in the same

way, we find that the CuZn alloy is composed entirely of the dark etching constituent, the Cu_2Zn entirely of the other, while in those alloys of intermediate composition there is always a mixture of the two substances, and the proportion of them varies just as the composition would lead one to expect.

Now returning to the question of corrosion. The etching by the acid which reveals the structure is simply a case of corrosion. Here we have two distinct metals, each by itself corrodible by the acid. They are in excellent electrical contact and are both immersed in a corrosive medium. Galvanic action ensues, the one least corrodible is preserved through the contact with its neighbor, which, however, is more vigorously atacked and eaten away by the acid. So far the matter is simple, and this explains what used to be considered to be so very mysterious, the decay of Muntz metal and somewhat similar alloys when exposed to the action of sea water. Some examples of this decay are here shown.

There were exhibited portions of a Muntz-metal condenser-tube plate and of a Muntz-metal diaphragm plate, some specimens of decayed yellow metal bolts taken from wooden ships, some brass bolts taken from a circulating-pump chamber, and a metallic air-pump valve. The latter was apparently sound, but it could be easily broken up by the hands.

It will be noticed that in each case where a decayed piece of metal has been broken the surface appears to be dull and non-metallic; where, however, the piece is filed it has a yellow metallic appearance, giving practically no indication of its actual character, although a careful comparison with a piece of sound metal similarly filed will show a distinct difference in brightness. How is this to be accounted for? If we take as an illustration a wall built with red bricks and white mortar, and supposing the bricks are stronger than the mortar, then if the wall is broken down by force the ruptured surfaces will show principally the white color of the mortar. If, however, the wall is sawn through or carefully cut right through the bricks without dragging any of them out bodily, the fracture

will show mainly the red color of the brick. It is similar in the case of the decayed Muntz metal. In the sound metal the two constituents are mixed up mechanically. One of them then becomes decayed, and then it is represented by the mortar of the illustration, the other remains practically sound and is represented by the bricks. On fracture by blow the rotten portion gives way, and we observe its color as dull brown, but on filing the metal some of the sound portions are filed through and we get the bright metallic appearance.

It may reasonably be asked why is it that in some cases the metal which decays or corrodes seems to do so in a different manner from that shown in the specimens exhibited, and disappears entirely without preserving its outward form? The explanation is probably to be found in the variation of the intensity of the corrosive influence. Where there are no extraneous electric currents to assist in the corrosion, but only the action of pure sea water, then the decay is slow and affects only the one constituent. It probably consists of a slow oxidation of the zinc, leaving the copper in an extremely finely divided metallic state. The zinc oxide in part must get dissolved away, because the total volume of the decayed metal and oxide is only equal to that of its original bulk, but in part it surrounds the minute pieces of copper left and partially insulates them. If, however, there is, in addition to the chemical action of the water, an added electric current, the action may be sufficiently strong to oxidize not only the zinc but also the copper, and the effect of the current then falls on the other constituent, and it also begins to oxidize and decay with the result of the formation of a pit hole or the loss of original shape. If the added electric current is strong it may actually from the first overcome the protective influence of $CuZn$ on the Cu_2Zn, and then corrosion of both constituents will take place simultaneously.

The effect of impurities in metals may be inferred to be the following. If the impurity is of a nature to be dissolved uniformly into the metal so that the impure metal is homogeneous, local currents will not be set up at all, and the impure

metal will be only subject to corrosion pure and simple, and will either tend to be preserved or to be more rapidly decayed according to the effect the impurity has. For instance take a brass which has not a duplex structure, say that used in ordinary condenser tubes, 70-30 as it is called. If there is a little tin in it, either as an impurity or intentionally added, the tin diffuses uniformly through the metal with the effect of retarding or diminishing corrosion. If, however, the impurity be a small proportion of lead, it also will be diffused or dissolved uniformly through the brass, but its presence will render the brass more corrodible.

When we come to more complex alloys, we in general get a still more complex structure than in ordinary Muntz metal. Most, if not all, of the so-called special bronzes used for propellers, etc., owe their strength to the iron they contain. They are mainly copper-zinc alloys of the Muntz-metal type, with a small proportion of iron, tin, and sometimes of other metals. The tin appears to go into solution with one or other of the constituents, and cannot be separately observed. The iron probably combines with some of the zinc, and the compound dissolves in the metal so long as its proportion does not exceed that at which the metal becomes saturated, which I believe is with about 1 per cent. iron. When, however, the iron exceeds this 1 per cent. there can always be seen in a prepared polished section of annealed metal numerous small points harder than and of different color to the rest, and these contain the excess of iron combined most probably with zinc. When etched these points are the first to be attacked and dissolved. These bronzes do not always behave in the same manner. In iron or steel vessels they generally last well. In several composite vessels with coppered bottoms the bronze propellers made for the different vessels by different makers all behaved in the same way; they became dezincified on the surface. In the first case noticed this was attributed to the vessel lying for a long time in impure river water. The propeller was filed bright and the ship was then employed in deep sea water, and it was found that the same thing occurred in the new conditions. In sub-

sequent vessels the same action took place. Now in iron or steel vessels this kind of action has scarcely ever been noticed. It was, therefore, reasonable to infer that it was due to the exceptional circumstances of the vessel being coppered. In fact, the bronze propeller and the copper sheathing immersed in sea water formed a galvanic battery.

Leaving the bronzes now, let us turn to cast iron, which is well known to suffer severely from decay in certain conditions, although in other conditions it remains good for apparently an indefinite time. Cast iron is perhaps the most complex in structure of all the metals used in every-day work, as also it is the most varied in chemical composition. Every known brand of pig seems to have a different composition depending on the ores from which it is smelted, while even from the same blast furnace working with the same coke, ore and flux, different grades of pig are produced. In all cast iron we have besides iron a considerable proportion—sometimes as much as 3.5 per cent.—of carbon, some of which may be combined with iron, forming carbide of iron, whilst the remainder exists as graphite; we always have also present in various proportions silicon, sulphur, phosphorus and manganese, all of which are recognized as ordinary constituents, and often we have other elements such as copper, arsenic, etc., as well, which are looked upon as impurities. Each of these elements, according to its amount, influences the physical properties of the iron.

When the iron is molten the whole of the elements, however they may be combined amongst themselves, must be in a liquid form uniformly diffused through the mass, and the molten cast iron is homogeneous or mainly so. On cooling, the first to solidify and to separate out is some of the carbon, which separates out in plates or partly spherical shells of graphite. If the cooling is very slow these graphite plates separate out in larger sizes than where the cooling is more rapid, and the iron is more grey and soft. Next, other parts separate out. The silicon combines with iron and manganese, forming silicides. The remainder of the carbon combines also with iron and manganese, forming carbides. The sulphur combines with some iron,

forming a brittle slag-like substance FeS, iron sulphide, which separates out in small particles throughout the mass, and finally the portion which solidifies last is a compound of iron and phosphorus. When cast iron is carefully prepared for examination by polishing, the graphite plates can be clearly seen, even with small magnification, as can also the small particles of iron or manganese sulphide, but the rest of the materials remain bright. By etching, however, and by heat, tinting the different constituents can be seen and recognized, and it is found that the phosphide of iron is always at the greatest distance from the graphite flakes, occupying, it may be said, the center of the spaces between the flakes. In this complex metal we have the very conditions for galvanic action to be set up directly a corrosive medium envelops the cast iron. The minute graphite plates are not readily oxidizable, they immediately become the minute poles of a multitude of miniature galvanic batteries. The phosphide of iron also appears to be very resistant of oxidation, so that the parts of this constituent also probably serve as poles of other minute batteries. At any rate we have every condition for a rapid oxidation of the surface.

Now let us see how the decay of cast iron proceeds. It is only too common to find iron castings which have been subject to the influence of sea water softened so that they can be cut with a knife, and in this condition they are generally said to have been converted into plumbago. By carefully preparing a section of a wasted casting at the junction of the sound and unsound portions, it can be seen that the decay first attacks the iron at its junction with the graphite plates; it then advances along the plates, and then gradually proceeds through the metallic portion surrounding the plates, leaving the phosphide compound till the last. Moreover, it is found that these phosphide portions have not only been left to the last because they have been the last attacked, but they are left intact in parts which have evidently been decayed for a long time, so that it is clear that they themselves offer a great resistance to corrosion.

So far we are considering corrosion of cast iron by itself, but it will be seen that given in addition a galvanic current in

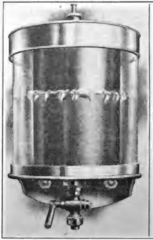


Fig. 3.

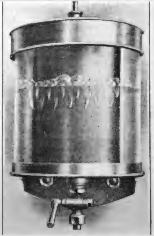


Fig. 4.

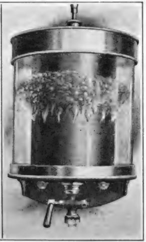


Fig. 5.

the right direction from an outside source we need not be surprised at the rapid rate at which corrosion will occur. Now again let us consider another point. If the corrosion is simply oxidation, then iron oxide, being practically insoluble in water, will itself form a thick coating of rust on the cast iron, which although it will probably transmit oxygen through itself, as mentioned in the earlier part of the lecture, and lead to further oxidation, it will not in any way account for the plumbago-like condition in which decayed cast iron is sometimes found. To account for this it is evident that plain oxidation is insufficient, and that there must be, in some way, other corrosive influences which permit of a solution or partial solution of the products of decay and the consequent removal of some of the iron.—"The Steamship."

THE "CONTRAFLO" SYSTEM OF CONDENSATION.

At the last spring meeting of the Institute of Naval Architects a paper was read by Mr. D. B. Morison in which reference was made to a new type of "Contraflo" condenser then being fitted in a cargo boat. Prior to the departure of this vessel on her first voyage some very interesting data were obtained, and the estimated results were fully realized. The feature in the system, apart from the particular disposition of the condensing surface, is the regulation, within limits, of the volumetric efficiency of the air pump by the control of its temperature.

It is well known that the presence of air in a condenser seriously affects the surface efficiency and lowers the vacuum, so the practical question is how it can be best dealt with. Clearly, the access of air to, and the accumulation of air in, a condenser cannot be ascribed to the action of the condenser itself. Whatever may be the reason for the air gaining access, its non-removal is at any rate directly due to insufficiency of the air pump, which insufficiency reacts on the condenser performance in such a way as to intensify the general effect. The precise manner in which air degrades condenser performance is,

perhaps, best understood by the consideration of what happens inside a condenser at work in which air is permitted to accumulate. The primary cause of the accumulation is the inability of the air pump to cope at the then existing vacuum with the quantity of air entering the system. Air being heavier than steam at all pressures obtaining inside a condenser, gravitates towards the bottom and forms an air layer, the depth of which increases until the pressure due to its weight and bulk rises to such an extent as enables the air pump to extract per unit time the same weight as gains access. Then, and only then, will equilibrium be attained, and the condenser will now be working with a greater or less proportion of its surface drowned in air, to which surface the steam cannot penetrate. The immediate result is that the effective condensing surface is reduced, the condensation rate of that portion of the surface which remains effective is increased, the temperature of condensation is raised, and the vacuum is lowered. Anything which increases the air-extracting capacity of the pump will therefore decrease the air ratio in the condenser bottom, and thereby increase the effectiveness of a greater proportion of the condensing surface, with the result of lowering the condensation temperature and raising the vacuum.

A sufficiently large pump is an obvious preventive of air accumulation; air leakage is not only variable, however, but the difficulty of its removal increases in tropical sea-water temperatures, so that a volumetric capacity of pump sufficient to deal with these conditions often involves an abnormal size. But if the temperature of the water passing through the pump can be adjusted, relatively to the temperature of the condenser, so that the condenser can be effectively rarefied at all times, it follows that the size of the air pump may be reduced to a minimum to meet normal conditions; and whenever extra duty is demanded it can be met by temperature adjustment.

It is this control of temperature which is the feature of the system as fitted in the S.S. *Gwladys*, and our illustrations show two views of the engines and condenser with the pumps removed. The size of the condenser is smaller than usual by

reason of the effective disposition of the surface and the particular arrangements for obtaining high thermal efficiency. This was fully dealt with in the paper already referred to, which we published in full on page 532 of our last volume.

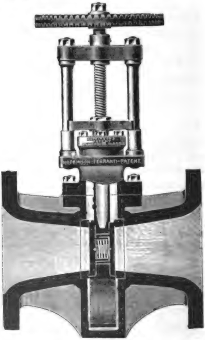
The economical vacuum for a reciprocating engine, and especially a cargo-boat engine, is, as is well known, much lower than for a turbine, and the S.S. *Gwladys* is designed to maintain 26½ inches to 27 inches all the world over. On the trials, which were under the direction of Mr. Robert Bruce, of the Contraflo Company, and the technical staff of Messrs. Richardsons, Westgarth & Co., a vacuum of 28½ inches was obtained with an unusually small quantity of circulating water, and on the vacuum being reduced about 2 inches by air leakage, it was at once raised again to the normal by regulating the temperature-control valve shown in the illustration. The flexibility so given to the air-pump capacity is thus available whenever required, with the result that the maintenance of the economical vacuum is assured under all reasonable conditions, and, what is of first importance in the economics of a cargo boat, the temperature of the feed water approaches the vacuum temperature as closely as the prevailing air leakage will permit; or, in other words, the thermal efficiency is the available maximum.

The S.S. *Gwladys* is also the first steamship in which the air gauge invented by Professor Weighton has been fitted, and its great value was fully demonstrated on the trials. At present the amount of air passing through a condenser is quite an unknown quantity, and the engineer in charge has no means of ascertaining whether the air leakage is within the capacity of the air pump, or whether a large portion of his condensing surface is air-drowned. This, in view of the degrading influence of air in a condenser, is a serious matter, but the simple apparatus, of which three illustrations are given in Figs. 3, 4 and 5, annexed, gives the engineer complete control of the position; and not only can the condenser be maintained at the highest efficiency consistent with the normal air leakage, but the power expended by the air pump and the circulating pump may

be reduced to a minimum. The apparatus has already been described by us on pages 507 and 508 of our last volume; but the illustrations now given show in a very striking manner the different effects produced by increasing quantities of air passing through the air-gauge.—"Engineering."

THE HOPKINSON-FERRANTI STOP VALVE.

Attention is being specially drawn to the Hopkinson-Ferranti stop valve. Although the valve proper is only half the diameter of the pipe, the design is such that it converts the pressure of the fluid into velocity and reconverting the velocity into pressure, thereby passes an amount of steam equal to the full carrying capacity of the pipe.



THE HOPKINSON-FERRANTI VALVE.

For this type of valve a number of special advantages are claimed, the first of these being that it halves possible leakage, because the perimeter of the valve disc and seat is one-half that of an ordinary valve. The reduction in the size of these parts also reduces the warping with high temperature, superheated steam still further reducing leakage. There is only one-eighth part the work to do in opening and closing the valve. Owing to the graded opening there is no sudden rush, as in ordinary valves. The joint making for the lid and handling of parts is estimated to be equal to that of a valve half the ordinary size. All expansion and contraction, either endwise or in a lateral direction of the pipe, is amply provided for, and therefore the valve cannot stick fast under any conditions of varying expansion or mechanical strain, as valves with wedging mechanism do.

The discs and seats are of Hopkinson's "Platnam" metal which withstands the temperature of high-pressure superheated steam. The discs are free to rotate on their axes, so that in opening and closing they slide upon their seats with a flexible pressure, which cleans the faces and prevents them being cut and scored by grit. It is further claimed that the Hopkinson-Ferranti valve is not subject to any wedging action of mechanical strains, and that when the valve is open and working the seats are sheltered from the steam flowing through the valve, while neat and uniform lagging with the pipes is facilitated.

FROM THE THAMES TO THE CLYDE.

The new shipbuilding and engineering establishment of Messrs. Yarrow & Co., at Scotstoun, on the Clyde, is now in full working order, all the building slips being occupied, and two torpedo destroyers for the Brazilian navy—the first fruits of the new works—occupying the covered-in tidal basin which is a unique feature on the river. The engineering and the boiler-making sections of the works are now complete, and the boiler-making facilities are sufficient to meet any demands en-

tailed by the projected destroyers and other classes of ships of this year's naval program. The works now give employment to considerably over 1,000 men.

Although the Yarrow shipyard is by no means one of the largest shipbuilding establishments in this country, its transfer from the Thames to the Clyde has become so universally known that it may be of interest, now that the move has been effected, to ascertain whether the expectations of the heads of the firm have been fully realized, and, if so, in what respects the wisdom of the move has been proved.

The reason which impelled the firm to leave the Thames for the Clyde was not that of making more or less profit, but of existence, because it was self-evident that the cost of production on the Thames was every day becoming more and more prohibitory, and a move was deemed to be absolutely necessary.

In estimating the relative advantages of various localities suitable for shipbuilding, the following conditions were taken into account:

1. Ample supply of labor.
2. Close proximity to the steel industry.
3. Invigorating rather than depressing climatic conditions.
4. Good educational advantages for the rising generation, and easy range of pleasant residences for staff and workmen.
5. A good measured mile for speed trials.

The locality which seemed to conform best to these conditions was Scotstoun, on the Clyde, and in comparing the cost of production there and at Poplar results have shown that it is less at the new site by 12 to 15 per cent. In London it appeared that all kinds of obstacles were put in the way of the development of the industry. The Scotstoun works are exactly the same size as the Poplar establishment; but, while the rates at Poplar were over £1,600, a year, the present rates are considerably less than half that sum. When the company desired that railway accommodation should be brought into the Poplar yard, various difficulties were placed in the way, while in Glasgow railway facilities were volunteered. Every block

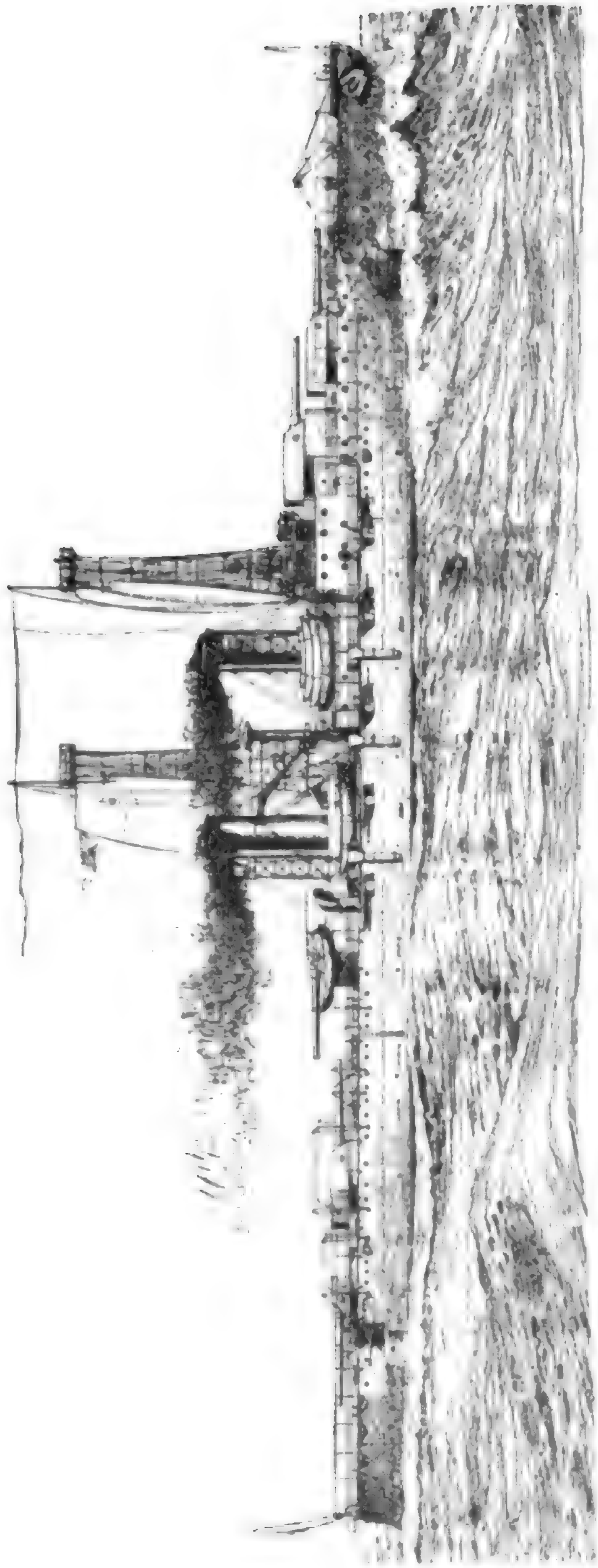
upon which a vessel was built, and every necessary pile placed on the foreshore of the Thames had to be paid for, while on the Clyde the authorities facilitated the company without charge in every way, provided it did not interfere with the navigation. In fact, in Glasgow there appeared to be a general desire on the part of public bodies to encourage industries, with a view to promote the general prosperity of the city.—"The Times," London.

SHIPS.

UNITED STATES.

The Launch of Our First Dreadnought.—The launch of the *North Dakota,* the first battleship of the *Dreadnought* type to be built for the United States Navy, which took place on November 10 at the Fore River yard, Quincy, Mass., is an event of more than ordinary naval importance. Although we seem to have lagged somewhat behind the foreign navies in building ships of this type, the British having seven or eight afloat, the Germans two or three, and the Japanese two, it must be remembered that in the *South Carolina* and *Michigan* we possess two ships afloat which, though they are of only 16,000 tons displacement, each mount eight 12-inch guns, and therefore, strictly speaking, belong to the *Dreadnought* type. The launch is also significant because of the rapid work which has been done upon this, considerably the largest vessel ever built for our Navy, its keel having been laid as late as December 16, 1907, and the ship at the time of the launch being nearly sixty per cent. completed.

The remarkable record made by the shipbuilders in launching the *North Dakota* in 10¾ months from the laying of the keel is noteworthy, when it is considered that although in one or two instances abroad a battleship has been launched in slightly over eight months from the laying of the keel, still in these cases the per cent. of completion of the foreign ships was not so great as in the case of the *North Dakota,* where 9,000 tons of material, or sixty per cent. of the ship, have been worked in in the record time above mentioned, and, in addition, much of the vessel's auxiliary machinery, fittings and equipment are already finished and ready for installation, including the five



THE 20,000-TON, 21-KNOT "NORTH DAKOTA."—OUR FIRST "DREADNOUGHT."

huge turrets in which will be installed the main battery of the vessel. These turrets are at present completed and lying on the dock alongside of the berth to be occupied by the *North Dakota* when she takes her initial dip, and the installation of these housings will be at once proceeded with. It is rightly considered, therefore, that the Fore River Company have made a world record in the construction of the *North Dakota* to date; and should the same rate of production be maintained for the forty per cent. yet to produce before the vessel is ready for trial it will result in all records for battleship building being at least equaled if not surpassed.

The accompanying line drawing, which has been reproduced from the working plans of the ship, gives an excellent impression of her general appearance when viewed from abeam, and also reveals for the first time many interesting particulars of her construction. The most striking feature is the two lofty steel lattice masts, each built up of hollow-steel tubing running in reverse spirals from deck to top platform. This platform will be occupied by the officers who will have charge of fire control; and it will be their duty to record the fall of the shots, determine the range, and telephone the results down to the officers in the various gun turrets. Note should also be made of the three openwork towers, each surmounted by a large searchlight. Compared with previous battleships, there is a distinct absence of top hamper in the way of lofty flying bridges, boat cranes and superstructures. The turrets are all arranged on the longitudinal center line of the ship, consequently the whole strength of the battery can be concentrated on either broadside. The secondary battery of fourteen 5-inch guns is mounted on the gun deck. Probably in future ships these guns will be mounted one deck higher, in order to lift them clear of spray and broken water. The *North Dakota* will displace 20,000 tons on her normal draught of 26 feet 11 inches. She will be driven by Curtis turbine engines of 25,000 horsepower at a speed of 21 knots. Her coal supply when the bunkers are completely filled will be 2,500 tons.—"Scientific American."

ENGLAND.

Gas Engines in H.M.S. Rattler.—For several years past the use of internal-combustion engines for the propulsion of ships has been discussed, more, however, from the academic than the practical point of view. It is a subject that gives scope for plenty of such discussion, for even supposing any kind of agreement to be reached on the main question, there is, as yet, room for endless differences of opinion as to the relative merits of the various types of gas and oil plants for marine purposes. Most of the points raised are such as can only be definitely settled by experiments on a practical scale, and until the results of such experiments are forthcoming no amount of theorizing will bring us any nearer the final solution of the problem. Up to the present, excepting the small craft coming under the heading of motor boats, very little has been done toward the actual development of the marine internal-combustion engine. To carry out experiments on any adequate scale requires not only a firm conviction of the future of the system, and a very considerable amount of money, but also a fair prospect of finding a use, or a purchaser, for any vessel so equipped. Moreover, for the experiments to have any chance of success involves a combined knowledge of both gas-engine and marine work, which is not always to be obtained.

The rarity with which such a condition can be fulfilled accounts for the almost negligible number of attempts by the advocates of internal-combustion engines to put their ideas into practice. It is easy to point out the advantages of such engines for marine purposes, and there is always the chance, by so doing, of getting some of the credit which more properly belongs to the man who eventually attains success. Among the first who did really practical work on the subject was the late Herr Capitaine, of Frankfort, who a few years ago constructed several small tug and other boats propelled by suction-gas engines. These were designed for use on canals, but one of his boats, the *Emil Capitaine,* was tried in the Solent in 1905, and created considerable interest. She was only of 16

tons displacement and had a speed of 10 knots; she was probably the first suction-gas boat to appear in the open sea.

Following on Herr Capitaine's work, Mr. William Beardmore, of Glasgow, decided to extend the same principle to vessels of a really sea-going type, for several designs got out by Mr. W. W. May, engineer of Messrs. Beardmore's Naval Construction Works, showed that a very considerable economy might be obtained over steam-driven vessels. The producer plant and engine together weigh anything up to 25 per cent. less than the steam plant for a corresponding power, and occupy less space. Moreover, the greater efficiency of the gas plant reduces the necessary bunker capacity, and allows more room for cargo. Messrs. Beardmore thereupon commenced the construction of a 500-horsepower suction producer and marine gas engine, destined to replace the steam machinery of H.M.S. *Rattler,* an old gun-boat used as a training ship for the Royal Naval Volunteers on the Clyde. The *Rattler* is 165 feet long by 29 feet beam, and formerly contained a set of triple-expansion engines. The change to gas engines was made by the influence of the Marquis of Graham, who is the Commander of the Clyde Naval Volunteers, and who, moreover, takes a keen interest in all engineering progress. Thanks to his efforts, and the enterprize of the above-mentioned firm, not only have the Volunteers a vessel in which they make cruises away from their base, but engineers are furnished with the first example of a large marine gas engine.

The engine on the *Rattler* is of the vertical single-acting open type, with five cylinders, and a fly-wheel abaft the first two. We illustrated this engine in our issue of April 13, 1906, before it was installed in the vessel, and hope shortly to be able to give full particulars of its construction. The ordinary four-stroke cycle is used, each cylinder being 20 inches in diameter, with a stroke of 24 inches, and developing 100 brake horsepower. The crank shaft runs at 120 revolutions per minute. The pistons are not water-cooled, and the open framing renders the connecting rods and cranks fully visible from either side. The design of the framing strikes one as exceptionally good.

It is constructed entirely of steel plates and angles, the plating being curved round to form the crank race, and continuing upwards on each side to support the cylinders. These latter, with their heads, are the only important details made in cast iron. The engine when running is perfectly steady, in spite of the apparent and actual lightness of the framing.

The valves are situated vertically in the cylinder-heads, the inlet valves in a row on one side of the engine, and the exhaust valves on the other. Each set is worked from a cam shaft running alongside the lower end of the cylinders, the cam shafts being driven by inclined bevel-geared lay shafts from the aft end of the crank shaft. The valves are all water-cooled, connections being made by flexible rubber tubes to a sort of cross-head on the stem. Low-tension make-and-break ignition is employed, each cylinder having its own magneto. Messrs. Beardmore consider this the most satisfactory for marine work on account of the absence of high-tension leads, and the apparatus on H.M.S. *Rattler* has justified this view by working faultlessly for the twelve months or more during which she has been in commission. Forced lubrication is used for the cylinders, but not elsewhere. Any cylinder can be shut off independently of the others, so that its valves, ignition, etc., can be examined, if necessary, while the rest of the cylinders are working.

Starting is effected by means of gas stored in reservoirs at a pressure of 95 pounds per square inch. This is turned on, and the engine moved by a bar. The compression-relief cams being in action, there is no compression in the cylinder, and the momentary automatic depression of a special starting valve allows the gas to enter immediately before the firing point. A baffle device of numerous thin plates prevents any possibility of a back-fire in the gas pipe. Moreover, the mixture cannot be fired until the admission valve is closed. As soon as the engine starts, the starting-valve gear and the relief-compression gear are, of course, put out of action. When, by the courtesy of the Marquis of Graham and the constructors of the machinery, we had the opportunity of having a trip in the *Rattler*, the

engines went away practically instantaneously—at the second stroke of the bar, in fact—and we understand they may be relied upon to do so. They are reversed by means of an hydraulic clutch and epicyclic gear. A description of the reversing gear would be unintelligible without drawings, which we hope to give on a future occasion. The principle, however, is well understood by engineers.

The suction producer consists of a cylindrical steel casing lined with fire-brick, and uses anthracite coal, which is admitted by means of a feeding hopper in the water-cooled cover. The fuel rests on trough-shaped bars arranged radially, with their inner ends resting on a water-cooled tube. The steam used by the producer is supplied by "boilers" arranged one on each exhaust branch of the engine. These are casings containing a nest of tubes, around which the exhaust gases pass. Besides supplying the necessary steam, the "boilers" effectively silence the exhaust. After leaving the producer the gas passes upwards through the cooling tower, which is simply a vertical pipe, down which water is sprayed. This cools the gas and removes dust and grit. Thence it goes to the centrifugal drier, in which a high-speed fan throws out all water, etc., which is drained away to a water seal. From the fan it passes to the cleaner, which is a square box filled with a labyrinth of closely-packed perforated plates, upon which settle any dirt or water that may possibly have escaped the action of the drier. Thence the gas goes to the engine. Very little useful space is occupied by the washing, drying and cleaning apparatus. Other auxiliary apparatus includes a small steam-driven compressor for filling the starting reservoirs. For this and other purposes on board for which steam is useful a vertical donkey boiler is installed.

From the brief description we have given it will be seen that the plant has been most carefully designed for the purpose in view, besides being of more than ordinary interest on account of its size and novelty. It may, or may not, be along the final lines which large marine internal-combustion plant may take; but it marks the first important step in the development of such

plant. On the occasion of our visit already referred to it ran perfectly in every way, and with no noticeable noise. Externally the engine may appear more complicated than the steam engine; but all that there is can be seen, and anything that is lost in the engine room is more than made up in the "stokehold." The smallness of the space occupied, and the slightness of the attention required were very noticeable, while the certainty of the absence of many of the troubles inherent in boiler plant is no small consideration at sea. Producers, no doubt, have their faults; but they are at their best when working under a steady load, such as marine practice involves.—"Engineering."

The Machinery of H.M. Battleships Agamemnon and Lord Nelson.—We return to the subject of these important battleships in order to describe the main engines. In our issue of September 4, on the two-page plate, No. XXI., we gave a front and end elevation and a plan of one set of the twin engines, and on the two-page plate this week we reproduce general drawings illustrative of the arrangement of the propelling engines and auxiliaries in the engine room.

The propelling machinery consists of two sets of four-cylinder triple-expansion engines, arranged in separate watertight compartments, with a longitudinal bulkhead (Fig. 9). These compartments are entirely independent of each other, there being no watertight door fitted in the longitudinal bulkhead.

The engines were designed to develop collectively 16,750 indicated horsepower at 120 revolutions per minute, with a boiler pressure of 275 pounds per square inch, and on the eight-hours' trial gave 17,285 indicated horsepower at 130 revolutions, with a pressure of 262 pounds. The diameters of the cylinders are: High pressure, 32¾ inches; intermediate-pressure, 52¾ inches; and each low-pressure, 60 inches, all having a stroke of 48 inches. All the cylinders are fitted with liners, those for the high-pressure and intermediate-pressure being of solid forged steel, and those for the low-pressure of cast iron. All the cylinders are steam-jacketed. The valves of the high-pressure and intermediate-pressure cylinders are of the piston

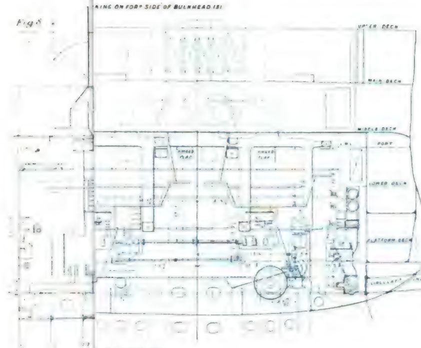
type, and those for the low-pressure flat double-ported slide valves, with relief-rings fitted to the back. The valve gear is of the double-link motion type. The reversing gear is of the all-round type, and independent links, arranged with adjusting screws to regulate the cut-off in each cylinder, are fitted.

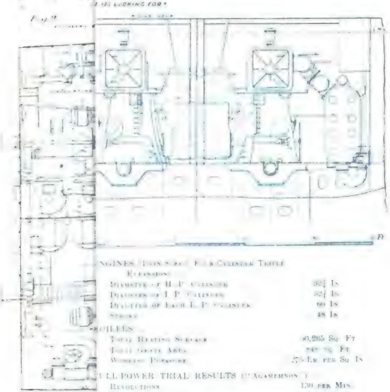
The bed plate, pistons and cylinder covers are made of cast steel, the front columns of forged steel, and the back columns of cast iron, of rectangular form and substantial section.

The shafting is hollow throughout, and for the *Agamemnon* engines was supplied by Messrs. W. Beardmore & Co., Limited. The diameter of the crank shaft is 17¼ inches, with 8¾-inch hole; the crank pin is 18¾ inches in diameter, with 10-inch hole, the length of the pins for the high-pressure and intermediate-pressure cranks being 21½ inches, and those for the low-pressure 13½ inches. The angles of cranks are arranged to balance the moving parts and give an efficient turning moment. The propellers are of manganese-bronze, 15 feet in diameter, and 19 feet pitch; number of blades, 4; and surface, 90 square feet.

The engines are fitted with forced lubrication, and the oil is supplied to the main bearings, crank-pit bearings, etc. Three pumps are fitted in each engine room. One pump is arranged to draw the oil from the save-all and to deliver it through strainers into the reserve oil tank, and also is connected to the ship's oil tanks to replenish the reserve tank in case of loss. One pump is fitted to draw from the reserve tank and deliver to the various bearings. The arrangements are such that the supply of oil can be regulated to each main bearing and crank pin independently. The third pump is arranged to either draw water from the save-all, to draw oil from the save-all, and deliver through the strainer to the reserve oil tank, or to draw oil from the reserve tank and to deliver to the various bearings, and therefore can be used for duty for either of the other pumps. Oiltight casings are fitted to incase all the principal moving parts, and these are carried to sufficient height on the engines to prevent spray escaping into the engine room.

Special bearing rings and springs are fitted at each end of





NGINES (TWIN SCREW, FOUR CYLINDER TRIPLE EXPANSION)

DIAMETER OF H. P. CYLINDER	32¾ In
DIAMETER OF I. P. CYLINDER	52¼ In
DIAMETER OF EACH L. P. CYLINDER	60 In
STROKE	48 In

OILERS

TOTAL HEATING SURFACE	40,285 Sq Ft
TOTAL GRATE AREA	848 Sq Ft
WORKING PRESSURE	275 Lb per Sq In

ULL POWER TRIAL RESULTS ("AGAMEMNON")

REVOLUTIONS	130 per Min
INDICATED HORSE POWER	17,285 H P
SPEED OF SHIP	16 735 Knots

GENERA *AGAMEMNON* AND *LORD NELSON* BA

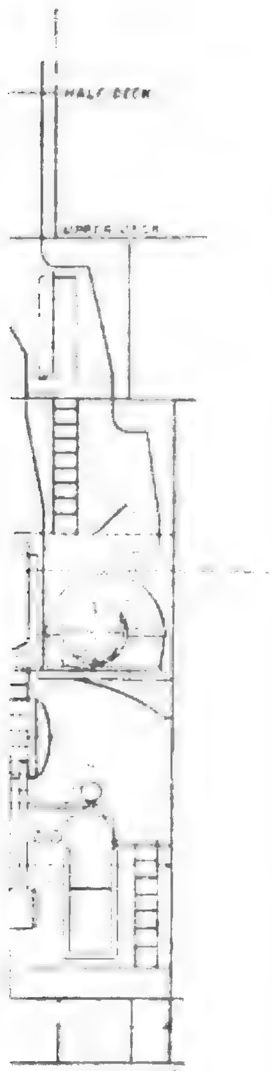
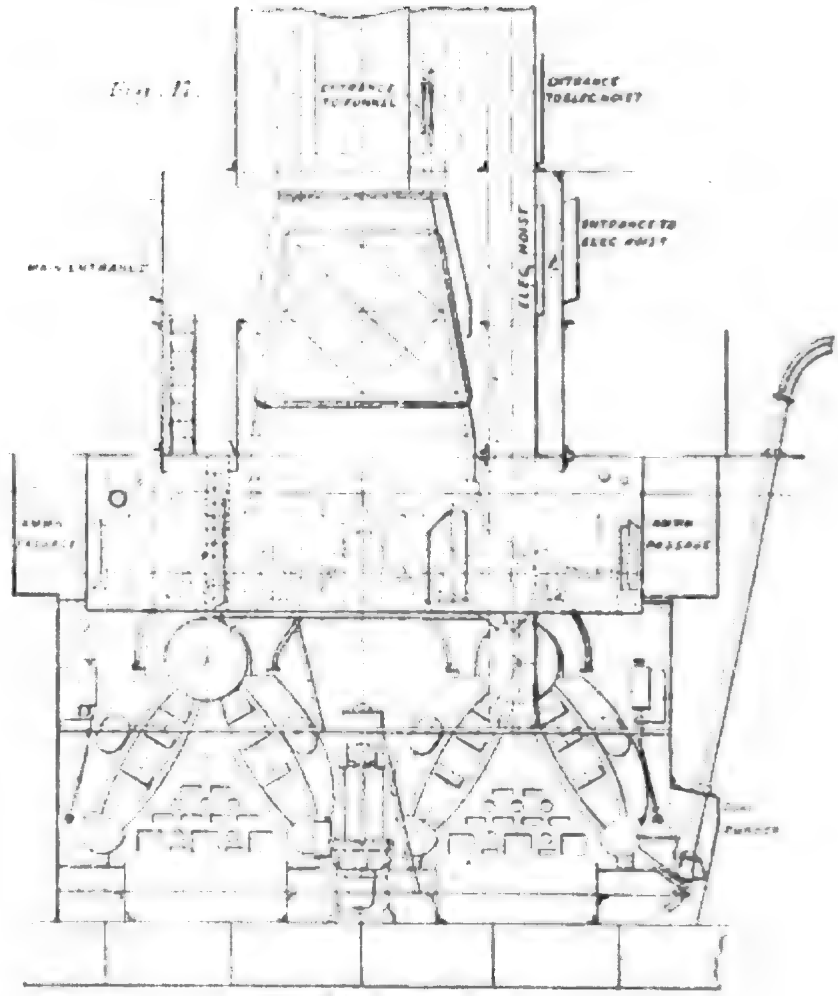
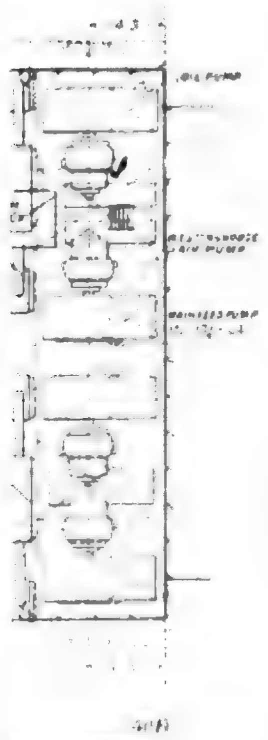


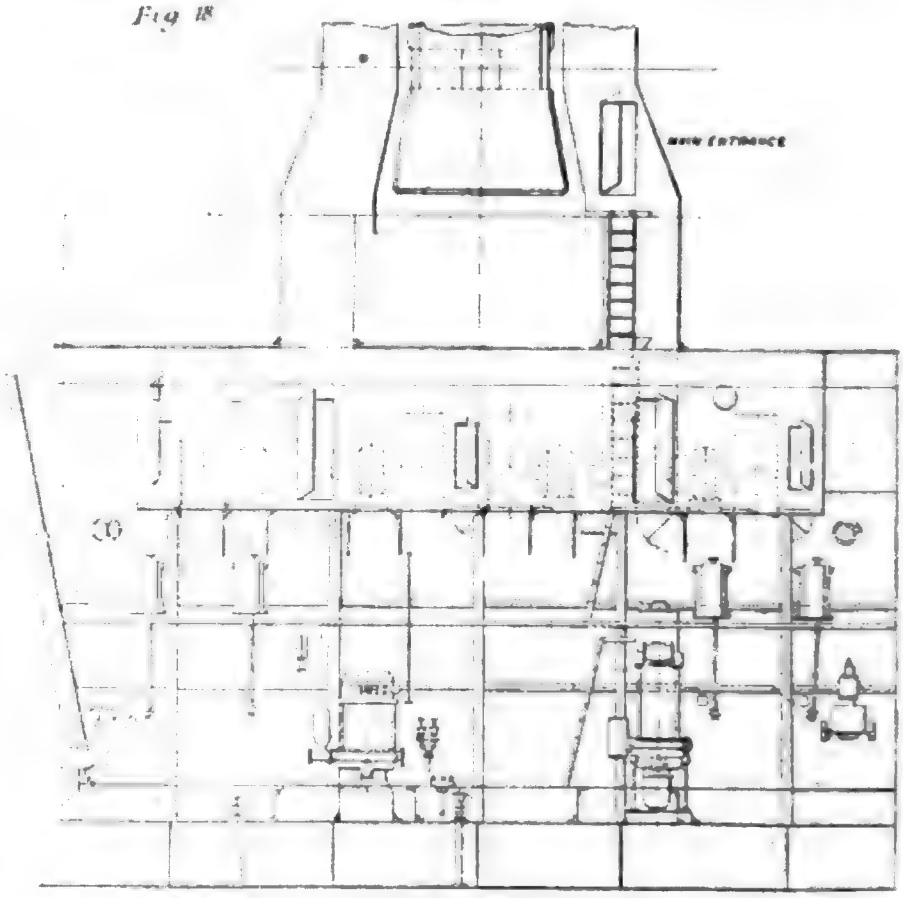
Fig. 17.



FRAME 66 & 67 LOOKING AFT

Fig. 18.





LOOKING FOR'D ON BULKHEAD 86

TTLESHIP *AGAMEMNON.*

the main bearing, to prevent excessive leakage of oil. The thrust block is arranged so that the collars are immersed in oil, and the shoes are made hollow and fitted with water-cooling arrangements.

Two condensers are fitted in each engine room, each having a cooling surface of 5,026 square feet. Two circulating pumps, by Messrs. W. H. Allen, Sons & Co., Limited, are fitted in each engine room, and are arranged so that each pump can supply either condenser.

Two twin air pumps, by Messrs. G. & J. Weir, Limited, are fitted, and draw from the condensers and deliver through the grease-extractor into the feed tanks. No auxiliary condensers are fitted in the ship. The auxiliary exhaust system is led to either the main condenser, low-pressure cylinder receiver or to the evaporator coils.

The distilling plant, by Messrs. J. Kirkaldy, Limited, consists of two evaporators and one distilling condenser in each engine room, and the total output of plant in the ship is 180 tons per twenty-four hours, the distilling condensers being capable of condensing all the steam made by the evaporators.

Fire and bilge pump and drain-tank pumps, by Messrs. Henry Watson & Sons, are also fitted. The engine-room arrangements are identical in both ships.

We complete our illustrations of these two important battleships by giving on Plate XXVI. the general arrangement of the boilers in the *Agamemnon*, the machinery of which was constructed by Messrs. R. & W. Hawthorn, Leslie & Co., of Newcastle-on-Tyne. The boilers in this case were of the Yarrow type; in the *Lord Nelson* they were of the Babcock & Wilcox type, but, with this exception, the installations are not dissimilar. The total heating surface is 50,265 square feet, and grate surface of 848 square feet.

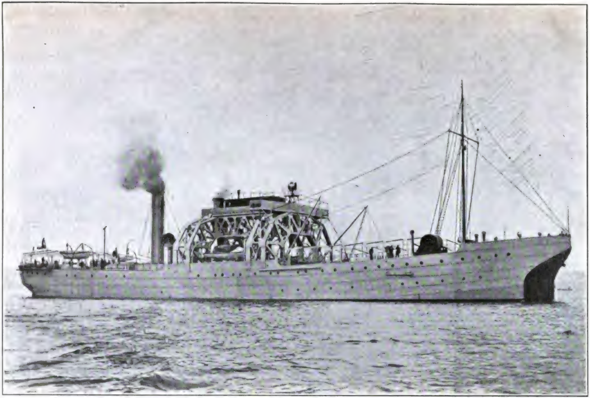
Twenty electrically-driven Sirocco fans by Messrs. W. H. Allen, Son & Co. are fitted, and three-fourths of these are capable of supplying the air required when the main machinery is developing full power. One main and one auxiliary feed pump, by Messrs. G. & J. Weir, Limited, is fitted in each boiler

room. Two ash-ejector pumps, by Messrs. Clarke, Chapman & Co., are fitted, and three ejectors, by Mr. F. J. Trewent, one ejector in each boiler room. One air-compressor engine, by the Westinghouse Brake Company, is used in each boiler room, and is used for sweeping the boiler tubes.

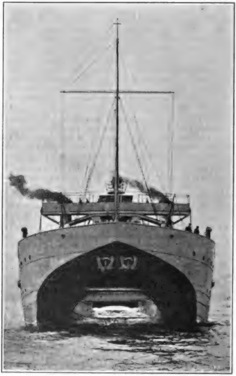
The three steam-driven electric engines and dynamos are of the Brotherhood-Laurence-Scott combination. Two oil-driven dynamos are supplied by Messrs. R. Hornsby & Sons, the dynamos being of Laurence-Scott manufacture. The steam and *oil-driven* dynamos are fitted to run parallel. Two sets of vertical steering engines are fitted by Messrs. Napier Brothers, Limited, and are arranged on the aft bulkhead in the engine room; a clutch is fitted to the shafting between the engines, so that either engine can work the gear at the rudder head.

GERMANY.

German Naval Dockship Vulcan.—The dockship *Vulkan* has recently been placed in commission in the German navy. It has been built in accordance with the plans of the Imperial naval constructor, Ph. von Klitzing, of Kiel, by the Howaldtswerke at that place. The distinguishing feature of the *Vulkan* is its peculiar form. The vessel itself consists primarily of two hulls, both resembling ships linked together fore and aft above the water-line by steel girders made up of angles and plates. This linking or joining together is done in such a manner that a torpedo boat or submarine riding at the surface can steam between the two hulls. When the small craft is in this position tackles and crane hooks can be lowered from the dockship, and the little vessel can be lifted out of the water and docked. After that, from both of the inner sides of the dockship, beams are swung under the smaller vessel, so as to form a platform on which she may rest. The beams are fastened by hinges to the inner side of the dockship. That is to say, they are fastened to the inner side of one of the hulls, and are pulled up against the inner side of the other hull as far as it is advisable to raise the docked boat. These beams



The German Dock Ship "Vulkan."



DOCKSHIP "VULKAN."

play no actual part in the raising of a vessel, that action being performed wholly by the cranes and tackles on the dockship. The center of the dockship is free, and the submarine or torpedo boat may be raised as far out of the water as desired. The hoisting or lifting apparatus is arranged on two double portals or bridges built up of lattice girders, the bases of which girders rest on the decks of the two hulls. These girders also serve as a rigid connection between the two hulls.

The means of propulsion of the vessel are interesting, for neither reciprocating engines nor turbines, but electric motors, are employed for driving the two propeller shafts. Current is delivered to the motors by two independent turbine generator sets. If the vessel is to steam slowly one generator set only is run. All the switches and controlling mechanism for the entire machinery are operated from the bridge, so that no intercommunication between the commanding officer and the engine room is necessary. Steam is generated in four Mehlhorn water-tube boilers.

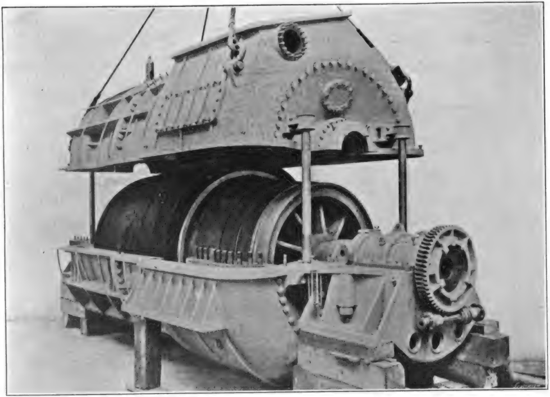
One of the purposes for which the vessel is destined is to serve in salvage operations for sunken submarines, the necessity for such a salvage ship having become more and more apparent as the development of submarine practice has progressed. The trials of the ship have, so we gather, been very satisfactory—so much so, in fact, that a second and larger ship of the same type is under consideration for the other great German naval bases.

Views of the *Vulkan* are given, one of these showing the vessel just after she left the launching ways. These show excellently the form of the vessel.—"Engineering."

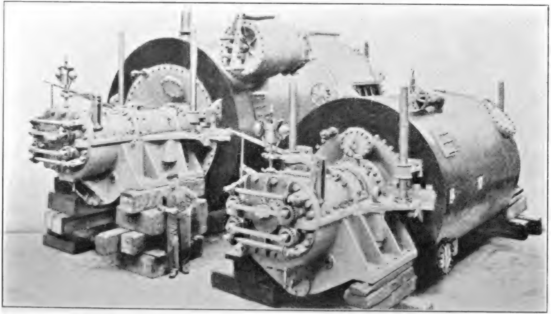
MERCHANT SHIPS.

Triple-Screw Turbine-Driven Pacific Liner Tenyo Maru.—The completion of the new Pacific liner *Tenyo Maru,* the first of the three sister ships for the Toyo Kisen Kaisha (Oriental Steamship Company of Japan), was undoubtedly an event of first importance in the shipbuilding and engineering industry on the Pacific Coast, as the vessel is not only the largest ship yet built in the East, but is the first steamer in Pacific waters fitted with turbines, and the Mitsu-Bishi Dockyard and Engine Works, who designed, built, engined and entirely equipped the vessel, are to be congratulated on the results of the work. In this ship we have practically the highest development of shipbuilding and engineering work, and modern examples of Eastern decorative work.

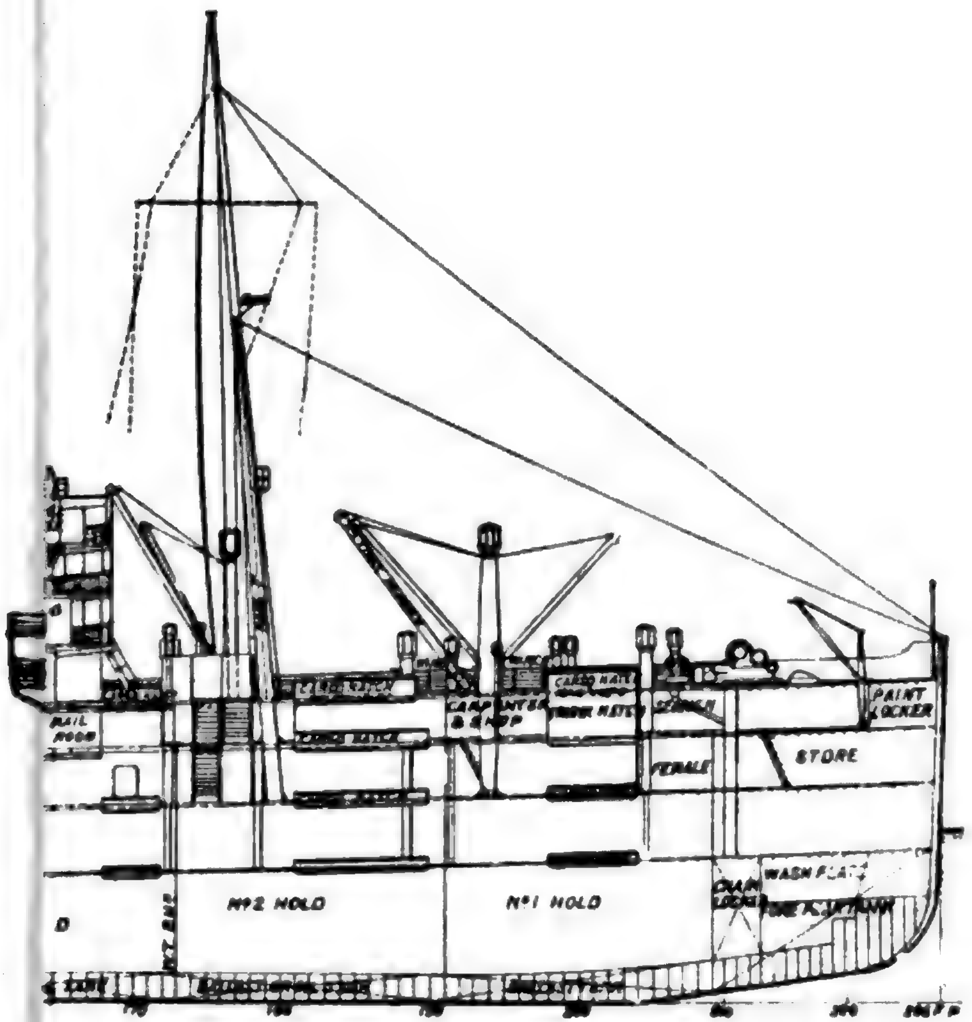
The Design.—It was in the middle of July, 1905, when the orders for two new Pacific liners were placed with the Mitsu-Bishi Works to the owners' design. The builders submitted alternative designs, proposing to adopt their own design on the ground that in this case the hull would be lighter by 200 tons. Turbines were suggested instead of reciprocating engines. Both proposals met with the approval of the owners, who showed the same measure of courage as did the Mitsu-Bishi Works, the licensees for manufacturing Parsons' turbines in the East. It is true that steam turbine machinery had at this time been fitted on a number of steamers in Europe, but they were of comparatively small displacement; the larger ships (since completed) with turbines were not then in service. As Mr. H. Maruta, the general manager of the Mitsu-Bishi Works, put it at the luncheon after the launching of the vessel on September 14, 1907, no one could help admiring the foresight, enterprize and courage which characterized the decision

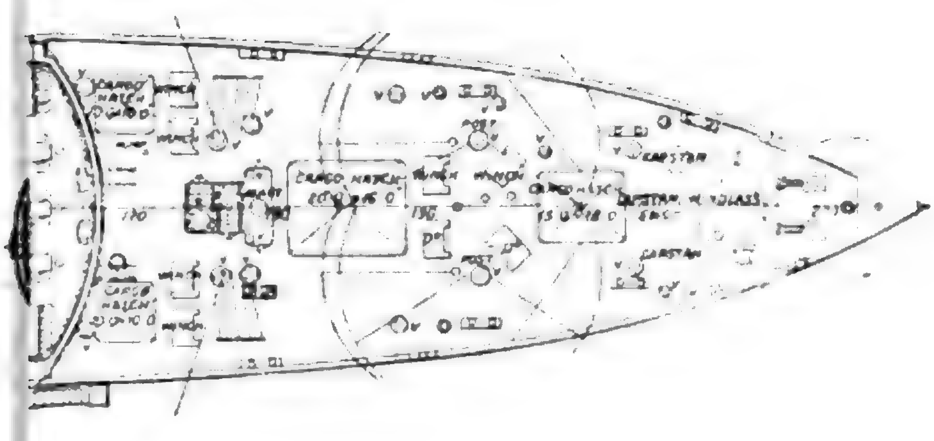


One Low-Pressure Ahead and One Astern Turbine of the "Tenyo Maru."

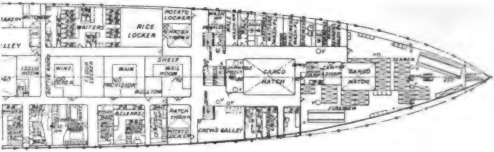


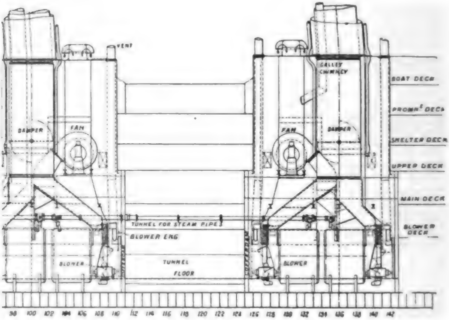
THE HIGH PRESSURE AND ONE OF THE LOW-PRESSURE TURBINES OF THE "TENYO MARU."


PAINT LOCKER
STORE
FEMALE
CARPENTER & SHOP
Nº2 HOLD
Nº1 HOLD
WASH PLATE

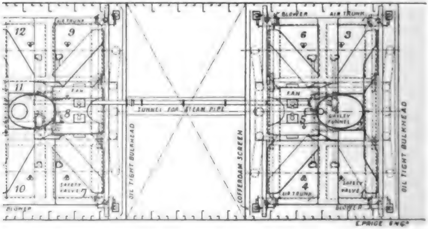

CARGO HATCH
CAPSTAN
WINCH

N KAISHA.





' to 11.



'HE TOYO KISEN KAISHA.

of the Toyo Kisen Kaisha in adopting the turbines in the new Pacific liners—a decision since proved to be fully justified by the results obtained in Europe. The decorative designs of the public rooms were entirely in the hands of Professor Tsukamoto, of the Imperial University, Tokio, by the owner's appointment.

Dimensions.—The principal dimensions of the vessel are: Length between perpendiculars, 550 feet; length over all, 570 feet 9 inches; breadth molded, 63 feet; depth molded, 38 feet 6 inches; loaded draught, 31 feet 8 inches; displacement at this draught, 21,650 tons; height from keel to roof of wheel house, 84 feet; height from keel to top of masts, 167 feet; height from keel to top of funnels, 129 feet; gross register tonnage, 13,454 tons; number of first-class passengers carried, 261; number of second-class passengers carried, 47; number of third-class passengers carried, 618; number of officers, engineers and crew carried, 250.

The Building of the Hull.—The first keel plate of the *Tenyo Maru* was laid on November 17, 1905, and she was launched on September 14, 1907. She proceeded on her official trials on February 19, 1908, so that she was completed within twenty-eight months. Had she been fitted with ordinary reciprocating engines this time would have been much shorter, for, owing to the equipment of new plant, etc., in connection with turbine manufacture, the machinery took longer to complete than would otherwise have been the case.

In the construction of the vessel 7,500 tons of steel were required. In many cases the plates have quadruple riveting. The flat-plate keel is fitted with a flat keel 2½ inches thick, scarfed, so that a flush surface is obtained for the entire length of the vessel. This is a great convenience in connection with dry-docking of the vessel. The flat-plate keel is 48 inches broad and $\frac{21}{20}$ inch in thickness, and the center girder plate is 53 inches deep and $\frac{13}{20}$ inch in thickness, and is secured by angles 5 inches by 5 inches by $\frac{13}{20}$ inch to the flat-plate keel, and 4 inches by 4 inches by $\frac{12}{20}$ inch to the inner-bottom plating. This construction is continued for the whole length of the ship, although the

thickness of the plates and bars is reduced at the forward and after ends.

The inner bottom of the ship is 50 feet wide at the central part, tapering towards the bow and stern to take the form of the ship. This structure is built up of floor plates at right angles to the center girder, of a depth of 53 inches, and extending nearly to the turn of the bilge. Fitted intercostal with these, there are on each side of the center girder three longitudinals, secured by angles and forming, with the plating, the double-bottom structure of the ship. This double bottom is used for carrying water ballast and oil fuel, and to give access to all parts. Incidentally it lightens the structure; holes have been formed in both the floor plates and intercostal girders. The fourth girder from the center line, known as the margin plate, is continuous fore and aft.

The side framing above the double bottom is of channel section 9 inches deep for the greater part of the length of the vessel. The spacing of the framing in the center part of the ship is 30 inches and at the bow and stern, where heavy angles take the place of the channels, it is diminished to 27 inches. These angles have reverse angle bars near the edge of the transverse flange. Each fourth frame in the machinery and boiler compartments, and each sixth frame in the aft hold, are of web section, built up of plates over ½ inch in thickness and 30 inches to 24 inches deep, with strong angles on the inner edge, and riveted to the shell of the ship. The web frames extend vertically to the upper deck. The web frames were built in the framing yard and were fitted there, with all connections hydraulically riveted, and in this state were subsequently moved to the building berth.

The main framing thus described extends to the shelter deck. The deck above this, forming the promenade deck for passengers, with central deck houses for cabins and public rooms, is supported by heavy tee-standards 6 inches deep and 5 feet apart. The boat deck, above the promenade deck, is supported by 2½-inch round-iron stanchions, also 5 feet apart.

The shell plating is for the most part $\frac{16-15}{20}$ inches in thickness and generally of 5 feet width of strake; it is almost entirely quadruple riveted.

The three topside strakes of the plating of the hull, which are of $\frac{22}{20}$ inch, $\frac{20}{20}$ inch and $\frac{20}{20}$ inch, respectively, and reduced at the ends, are double strapped and quadruple riveted; and the next two strakes, which are $\frac{18}{20}$ inch in thickness reduced at the ends, are quadruple riveted. The butts of the keel plates are double strapped and treble riveted.

Wherever possible hydraulic riveting was resorted to, and even before the rivets were put in the plates and angles were forced and held together by hydraulic power, so that the temporary bolts and nuts should bring the surfaces as closely together as possible before riveting. In this way there was absolutely no possibility of yielding when the rivets were put in. The work done by hydraulic power includes the landing and doubling of the shelter-deck sheer strake, the strake below, and the shelter-deck stringer plates, bars, keel plates, and slab-keel plates. The rivets in the shell and tank top plating vary from ¾ inch to 1⅛ inches in diameter, spaced on an average 3½ to 4 diameters apart. In the bulkheads the sizes generally are ¾ inch in diameter, spaced 4½ to 7 diameters apart; the deck rivets are ¾ inch, spaced generally 4 to 4½ diameters apart.

The inner bottom plating ranges from 5 feet 9 inches to 6 feet in breadth of strake, and ½ inch in thickness, reduced toward bow and stern. It is, however, thicker in the boiler and machinery spaces, where further strength is imparted to the structure by a greater number of longitudinals, built intercostally with the floor plates. This inner plating is lapped and treble riveted, and joggled and double riveted at the edges.

There are twelve bulkheads, of which four are oiltight for oil-fuel bunkers, built of $\frac{8}{20}$ inch to $\frac{7}{20}$ inch plating with 7-inch angle stiffeners, extending to the lower deck and spaced 30 inches apart. These are connected by large brackets to the tank top plating and to the lower deck. The horizontal stiffeners are 9½-inch bulb angles spaced 48 inches apart. Above

the lower deck—*i. e.*, the 'tween-deck bulkheads—the stiffeners are $5\frac{1}{2}$ inch angles. The oiltight bulkheads are built of $\frac{10}{20}$ inch to $\frac{8}{20}$-inch plating with $9\frac{1}{2}$-inch bulb-angle vertical stiffeners, spaced 30 inches apart, and $9\frac{1}{2}$-inch bulb-angle horizontal stiffeners, spaced 48 inches apart. The bulkhead at the aft end of the machinery space, the bulkhead to the shaft tunnel, that between the machinery and the aft boiler room, and that between the aft and fore boiler rooms, are each fitted with watertight doors on the "long-arm" system. In the aft holds the level of the lower-deck flat is lowered to form the tunnels for the propeller shafts, and has a longitudinal bulkhead near the center line, and also one against the side of the ship on each side, forming fresh-water tanks.

The deck beams are of deep channels throughout, and are connected to the framing by knee brackets, and supported vertically and tied together by solid circular pillars and double channel-bar pillars, the latter being used for wide-spaced arrangement.

The deck plating is $\frac{11}{20}$ inch to $\frac{8}{20}$ inch in thickness, but is heavier where required, principally in the stringers or outside strakes of the deck plating, which are $\frac{20}{20}$ inch to $\frac{11}{20}$ inch, reduced at the ends, with extensive doubling in the main structural decks. The laps are joggled and single riveted. The butts are also joggled and treble riveted generally.

At the corners of the hatchways, engine and boiler casing openings, there are heavy plate doublings. The coaming of the hatchways, which are also of heavy plating, also add to the strength of the structure in their vicinity. To replace the ordinary deck beams removed in the engine and boiler openings, there are special strong beams built up of heavy plates and angles. In the boiler space opening they are 14 inches deep and connected and stiffened by heavy angles. In the engine space there are introduced five extra-heavy girders, 45 inches deep, arranged both as to position and spacing to permit of the turbines being raised from their seats.

As the lower decks of the ship are complete only in the holds, the longitudinal strength in the engine and boiler spaces, which

occupy the greater part of the middle part of the ship, is maintained by girders and stringers.

The engine seating is of fore-and-aft box girders worked on the top of the inner bottom, which is constructed throughout with the same lines of longitudinal and inner floor worked at the same height forward and aft. Upon these girders supports for the turbines were bolted. As the reciprocating stresses are eliminated, and the propeller thrust is almost steam balanced, the structure is much lighter on the whole than it would have been for reciprocating machinery.

The stem of the hull is of forged steel with cast-steel forefoot, so as to take easily all the ends of the plating. The stern post and brackets are of cast steel. The center propeller shaft, as shown in Figs. 13 and 14, on Plate XXXVIII, passes through an aperture as in a single-screw ship, and the stern post, after the arching up to give satisfactory clearance over the tips of the blades, is carried down abaft the propeller, very nearly to the level of the center shaft, for the purpose of giving sufficient length of bearing for the rudder post. Higher up, the post is considerably swelled out, as shown in both views, in order to satisfactorily house the steering gear, which is placed beneath the water line to meet the requirements for service as an auxiliary cruiser.

In designing the shape of the stern post every care was taken to insure clean entrances, in order to reduce friction and eddy-making to the lowest possible extent. At a time it was contended that the post was unnecessarily heavy in structure; but while the designing was in progress the gigantic American steamer *Minnesota,* which is fitted with a similar kind of stern post, although she is fitted with reciprocating engines and of much lower speed, was brought to the works for repair with a crack at the arch of the post, and this circumstance induced the designer to make more allowance in scantling than otherwise would have been. Again, for the transportation of the post over a great distance—in fact, from Great Britain to Japan—it was necessary to design it in several pieces, and to allow

sufficient bearing surfaces for bolting the parts together. Thus it is heavier than if it were in one piece.

The rudder is also of cast steel, in two parts, connected together by horizontal flanges, and, as will be seen from Fig. 13, revolves on two pintles, which together with the gland at the head form the whole support against sideway pressure when maneuvering.

A singular feature of the stern post is the provision of a slot over the rudder, introduced so as to make the rudder apparently continuous with the stern post, and yet give sufficient clearance to lift the rudder when unshipping. The rudder is wholly below the water line, and its area is 218 square feet.

All the above steel castings were supplied by the Steel Company of Scotland.

The Launching of the Ship.—The *Tenyo Maru* being the largest ship yet built at the Mitsu-Bishi Works, much care and forethought were expended on the design and construction of the launching ways. Her weight on this occasion was 7,923 tons, including the launching cradle.

There were nine bilge blocks on each side. The keel was laid with a declivity of $\frac{7}{16}$ inch per foot, and the standing ways $\frac{6}{16}$ inch to $\frac{12}{16}$ inch per foot. The camber was 31 inches in the whole length of 602 feet. The standing ways extended from 29 feet abaft of the fore perpendicular to 79 feet abaft of the aft perpendicular. The sliding ways had a bearing length, from the fore end of the cradle to the heel aft, of 470 feet 8 inches, and as the width was 4 feet, the total area of bearing surface was 3,652 square feet, which gave a pressure per square foot of 2.17 tons when the total weight, including the cradle, was taken into consideration. There was, however, at the moment the stern floated a much greater pressure at the forward cradle, and this affected not only the fore cradle and the ways, but the floors and tank-girder construction. The examination, however, showed that everything had been of sufficient strength to withstand the great pressure, which was calculated to be 1,820 tons, decreasing to 450 tons as the bow left the ways. The greatest draught aft before lifting was about 28 feet,

while the maximum moment against tipping was calculated at 382,000 foot-tons.

The ways were placed at 23-foot centers. They were constructed of Oregon pine. The average length of the timbers forming them was about 45 feet, built up of four logs, and the butts were scarfed and bolted together by five 1-inch bolts. The average length of the sliding ways was also 45 feet. On account of the fine bow, a strong shelf plate of steel was fitted and supported by knee brackets, in order to form a butting surface, or a bearing, for the vertical members of the poppets.

On the standing ways there was laid first a coating of tallow and wax, secondly a coating of tallow and seed oil, and finally soft soap in blobs about 6 inches apart. On the sliding ways there was laid, before they were turned in on the top of the permanent ways, a thin coating of tallow and wax; next, tallow and seed oil; and, finally, soft soap in blobs. The total quantity of tallow thus used was about 3.6 tons, and of soft soap 0.5 ton.

Every possible care was taken in the process of releasing the ship, and many distinct and pre-arranged electric-bell signals with reply system were adopted in carrying out the instructions.

There were two dog shores, but in order to avoid any possible danger which might occur by hanging such a big ship on the dog shores alone, keel blocks under the forward part of the ship, about fifty in number, had sand bags put in between the wood blocks instead of being built up entirely of wood, and were left in place till the last moment. The sand bags were ripped open just after the dog shores had been knocked down by the falling weights, and the sand allowed to escape. Pressure on the blocks was thus rapidly released, and the total weight brought on the launching ways. There were hydraulic rams of 200 tons pressure abutting on the head of each of the sliding ways, to start the vessel if necessary; but they were not brought into use.

The time occupied in the first 20 feet of travel was 10.85 seconds, while for the 602 feet, the total length of the standing

ways, the time was 51 seconds. The maximum speed was 19.76 feet per second, equal to 11.7 knots, and the maximum acceleration was 98 feet per second per second.

The draught forward when the ship was afloat was 10 feet $4\frac{1}{8}$ inches, and aft 16 feet $0\frac{3}{4}$ inch, with a mean of 13 feet 2 $\frac{7}{16}$ inches, the total weight being 7,593 tons, which excludes the 330 tons due to the launching cradles.

The Naming of the Ship.—The honors of the launch were performed by Mrs. Asano, the wife of the President of the Toyo Kisen Kaisha, who named the vessel the *Tenyo Maru.* It is interesting to note that "Ten" means "heaven" and "yo" the "ocean." The latter is also the second character of the owner's name Toyo, whilst the former is the first character in Chinese classic vocabulary called "Thousand letters," containing one thousand characters, and it is the wish of many that the Toyo Kisen Kaisha may continue to build ships for the remaining nine hundred and ninety-nine letters of the vocabulary.

The Passenger Accommodation.—The *Tenyo Maru* has six decks; the topmost, the boat deck, being about 33 feet above the load water line. Of this deck a plan is given on plate No. XXIX. Although it carries the large number of lifeboats with which the vessel is equipped, the greater part is available as a promenade for first-class passengers. At the fore end there is accommodation for officers, and at the aft end are the smoking room and lounge.

The next deck is known as the promenade deck, and it equals in length the boat deck. This deck is also arranged as a promenade, and an adequate idea of the area afforded is given by the plan, Fig. 3, on plate No. XXIX. At the forward end of the deck house are the drawing room, the reading room, and four suites of rooms, each consisting of a sitting room, bedroom, and a bath and toilet room. There are also four large family rooms. On the midship part there are four large staterooms specially well fitted, and at the after end there are nine ordinary state rooms. The public rooms on this deck and those on the boat and shelter decks are fitted with Messrs. J. Stone

& Co.'s vertical-motion ventilating square deck-house windows. The cabins and those of similar nature on the deck below are fitted with Messrs. J. Stone & Co.'s pivoted side scuttles with air inlet and outlet ventilating arrangement. The sitting rooms in the suites are each finished in different wood or style. A pair of folding berths and a sofa are placed to each room; the former is so designed that, when folded up, it assumes the appearance of a portion of the wall, having the berth bottom panelled like the wall, and the wall is recessed to receive the berth. Writing desk and dressing tables are also supplied. The rooms are upholstered in colored tapestry, which, with the different shades in carpets to match, gives a very fine appearance. The bedrooms are in correspondingly good taste, and Messrs. Hoskins & Son's "Neptune" bedsteads are fitted. The cabins on this deck are all finished in oak.

On the next deck, known as the shelter deck (Fig. 4 on plate No. XXIX), are located the dining saloon for first-class passengers, smoking room for intermediate passengers, and the hospital. There are also thirty-nine first-class state rooms. This deck marks the top of the molded structure of the ship, and therefore extends the full length of the vessel. But on no deck is the first-class passenger accommodation within 139 feet of the bow or 158 feet of the stern, while even the second-class passenger rooms are 125 feet from the stern. The importance of this point is associated with the reduction of disturbance of the saloon passengers, either from propeller action, which is, however, minimized on account of the adoption of turbines, or from the action of the sea, which is, perhaps, an insurmountable difficulty even with the greatest of ships. The special feature of the hospital is the introduction of Messrs. Hoskins & Son's patent equilibrium berths. Three of these are fitted in the hospital.

The upper deck (Fig. 5 on plate No. XXIX)—the first deck within the molded structure of the ship—has twenty-two cabins for first-class passengers, with auxiliary saloon, and a nursery for children. The intermediate-class accommodation is abaft the first-class quarters. There are sixteen cabins and a commo-

dious saloon. At the fore end there is accommodation for crew, and at the aft end for Chinese steerage passengers.

The main deck is entirely given over to the steerage passengers, forward for Japanese and aft for Chinese. On this deck 666 emigrants can be accommodated; Messrs. Hoskins & Son's patent galvanized-iron berths with sack bottoms are used.

There is one kitchen for the first and second-class passengers, with separate pantries adjacent to the respective dining saloon, also one for Japanese and one for Chinese. Many mechanical and electrical contrivances have been introduced by Messrs. Henry Wilson & Co., Limited, Liverpool, who supplied practically all the appliances, including patent roaster, steam stock pots, steam cooking boiler, grills, bain-maries, island ranges, steam ovens, bread and pantry ovens, rotary dough mixer, etc. The roaster has three revolving spits, two for joints and one for game, which are rotated by gear-driven electric motor. In the pantries there are carving table and hot press, bain-marie, milk, coffee and hot-water apparatus, electric dish-washing machine, egg boilers, etc.

The ventilation of the ship has had the most careful attention, and is associated with the heating appliances by means of the thermo-tank system, which will be referred to later, in connection with the electric equipment.

A special feature in the ship is the bath room and lavatory accommodation. Toilet apartments are arranged on all decks convenient to the state rooms. There are in all twenty-two bath rooms and twenty-five w.c.'s for first-class cabin passengers. The baths are all of white porcelain. The sanitary appliances were supplied from Messrs. Shanks & Co., Limited, Barrhead, Scotland, and Messrs. J. L. Mott's Iron Works, New York, U. S. A.

The ship is equipped with most improved laundry appliances, supplied by the Empire Laundry Machinery Company, Boston, U. S. A., including Cambridge washer, extractor and mangles, all electrically driven, steam-jacketed starch kettles, electric ironers, etc.

The Clayton apparatus is also fitted in the ship for fire extin-

guishing, disinfecting and ventilating the holds, bunkers and double bottoms.

The ship's boats are all fitted with Welin's quadrant davits, by which means any boat could be easily got out in spite of a considerable list which the ship may have at the time. Some of the boats are fitted with shifting chocks, permitting the boat to be chocked either fully inboard or along the extreme edge of the deck, so as to provide more promenading space on the boat deck.

Cargo and Navigating Appliances.—For dealing with the 6,000 odd tons of cargo carried fourteen derricks are fitted on the vessel, besides which there are two derricks, each capable of lifting 25 tons. In connection with these there are fourteen powerful steam winches.

The refrigerating installation is of Messrs. Hall & Co.'s combined and interchangeable type, including air cooler and water cooler, etc. The plant is capable of reducing the temperature of the insulated chambers from 70 degrees Fahr. to 20 degrees Fahr. in fourteen hours.

The installation of anchor gear in the vessel is by Messrs. Clarke, Chapman & Co., Limited. In the *Tenyo Maru* there are two cable holders for working the anchor cables, which are 2⅞ inches in diameter. Aft of the windlass are two capstans for warping, one on the port and the other on the starboard side. These are driven by the horizontal engine placed on the middle line of the ship. The engine has two cylinders, each 11 inches in diameter and 12 inches stroke, fitted with link-motion reversing gear and steam stop valve, and fitted with single and double-purchase gearing, and with clutch gear; so that either or both capstans can be worked at once. Two capstans are also fitted on the deck aft, similar to those in the fore part of the ship.

The steering gears are by Messrs. Brown Brothers, Limited, Edinburgh. There are two sets of steering gear, one located on the upper deck and the other on the lower deck well under the water line. The rudder itself weighs 27.5 tons, so that the gear is very heavy. The lower gear is designed to put the

rudder over in 20 seconds, the upper gear in 30 seconds. The connection of the upper gear is made by bolting a short fast tiller on the rudder head, to the bottom of the flat tiller carrying the steering engine, and the gear engaging in the quadrant.

The ship's telegraphs are all supplied by Messrs. Chadburn & Sons, Liverpool, including reply engine-room telegraphs, steering and docking telegraph, and Admiralty pattern tell-tales indicating "ahead" and "astern" of the machinery.

The Electric Installation.—In a ship of this class, carrying so many passengers, the electric installation is naturally an important feature in the equipment of the vessel, and an outline description of the appliances adopted will be of some interest. The generating plant, located on the main deck in the engine room, includes two generating sets, each giving an output of 75 kilowatts when running at 430 revolutions per minute. The large main switchboard has twenty circuits—eleven for the lighting of the ship, five for thermo tanks, one for ventilating fans, one for workshop machinery, one for galley machinery, and one for the searchlight projector. The lighting installation is arranged on the double-wire system. The mains of each circuit are led from the switchboard to a sub-main board, which again supplies three, four or six-way distributing boxes, each in its turn feeding four to eight-way small porcelain extension boxes, whence branch wires are connected up to the lamps. There are in all about 1,200 lights of the Tantalum type. The feeders for each motor are led from the switchboard to a double-pole fuse junction box with leads thence to each motor.

The thermo tank and ventilating fans form an interesting feature of themselves. The fifteen thermo tanks are fitted on the weather deck. They are designed for a threefold purpose. Each thermo tank can supply, through sheet-iron trunks, fresh air to the compartments, either cold or steam-heated to any desired temperature, or they can exhaust the foul air from the compartment. These operations are controlled by a series of lever-valves fitted in each thermo tank. The thermo tanks are capable of maintaining the temperature of the room at 65 degrees Fahr. when the outside atmosphere is 32 degrees Fahr.

The thermo tanks were supplied by Messrs. Stewart, of Glasgow.

The engine room is ventilated by four ventilators, each fitted with an 18-inch electric fan. As regards the ventilation of the saloons, state rooms and cabins, etc., there are 117 10-inch Portwayne bracket fans, ninety-eight for state rooms and nineteen for officers. There are also five 12-inch trunnion-bracket fans for the galleys and opium room. The dining saloon is ventilated by means of eight overhead fans, each 40 inches in diameter, the smoking room by one ventilator with 18-inch fan and five 10-inch trunnion-bracket fans, the lounge by four of 10-inch, the auxiliary-saloon by two of 12-inch, and the intermediate saloon by three 12-inch fans—all of the trunnion-bracket pattern.

As regards the telephone service, there are on the navigation bridge telephones communicating with the engine room, the lookout at the forecastle, the docking bridge aft, and the steering-engine room, all of pillar type. The telephones are of the loud-speaking marine pattern, and were supplied by Messrs. Alfred Graham & Co., London. In addition to the above there are intercommunication telephones fitted in the cabins of the captain, chief engineer and purser, also between three stations in the first-class accommodation (one each on the promenade, shelter and upper decks) and saloon pantry.

The navigation lights, telegraphs and principal compasses are also electrically lighted. There are 30 portable lamps for hold and bunker use, also eight cargo reflectors, each 4 to 50 candlepower lamps. The searchlight projector is of 16,000 candlepower. The navigation lights have a signal indicator placed in the chart room.

In connection with the watertight doors on the "long-arm" system, which are actuated by means of electricity, there are in the chart room controllers and an indicator board showing every door, and as the doors close the circuits in connection with each are cut in, and the lamps corresponding to each door are lighted up to show that the operation has been carried out.

Wireless telegraphy on the Telefunken system has been fitted, making the ship's equipment quite up to date.

Propelling Machinery.—Turning now to a description of the machinery, it may be said at the outset that the Mitsu-Bishi Company, when they obtained the right for manufacturing the Parsons steam turbine in Japan, realized that it was absolutely necessary to impart a thorough practical knowledge to their staff of the method of manufacture and the actual running under sea conditions of the turbines. They therefore despatched Messrs. Esaky, chief draughtsman in the engineering department, and Araki, the foreman fitter, both of them engineers of long and varied experience, to the Parsons works, where they spent a year, returning in time to instruct the foremen and men of the works, thoroughly to prepare for the fitting out the turbines of the *Tenyo Maru.* The turbines were constructed at the Parsons works and shipped out for the vessel.

There are three propellers, and as shown by the plans and sections of the machinery reproduced on Plate XXIX, the high-pressure turbine is on the center shaft, and one combined low-pressure ahead and an astern turbine on each of the two wing shafts. The turbines take steam at an initial pressure of 180 pounds. The low-pressure shafts are at 12-feet 6-inch centers on each side of the middle line of the ship. All the shafts are parallel with the middle line of the ship (Fig. 7), whereas they are at a slight angle to the line of the keel (Fig. 6). The intermediate shafts are of Messrs. Armstrong, Whitworth & Co.'s fluid-compressed ingot steel, whilst the propeller shafts are of Messrs. Richardson & Son's lock-fast iron, and about 20 per cent. heavier than the rule requirements.

The rotor drums are of forged weldless steel; the high-pressure drum is 76 inches in diameter, with over 130,000 blades, while the low-pressure drum is 106 inches in diameter, with over 300,000 blades, and the astern drum is 87 inches in diameter, with over 160,000 blades. Perhaps, however, a better idea can be formed of the magnitude of the work when it is stated that the total weight of the high-pressure turbine complete is over 67 tons, and of the low-pressure and astern turbine over 126 tons.

The illustration, Fig. 24, shows the method of assembling

the blades and forming them into segments, according to the latest practice at the Parsons works. It will be seen that for temporary use castings are made and bolted together to represent part of the circumference of the casing, or of the rotor, the former concave, the latter convex; and these form a groove exactly similar to that into which the segment is subsequently to be caulked in the casing and rotor respectively. The wire on which the blades and distance wedge pieces at the base are threaded, by holes suitably formed, is secured at one end of the casting, and by means of a caulking tool and hammer the lads string the blades and wedges alternately into place, ready for another workman to put into position the strip, and bind the blades together, as shown in Fig. 24. These strips fit into indents cut on the edge of the blade, and are laced by a wire and fixed with silver solder. In this way it is found possible to assemble the blades into segments while the casings and rotors are being machined, and the final operation of caulking the segments into grooves is quickly accomplished. The lacing of the blade gives greater security than the former practice of wedging each blade separately into the groove in the casing or rotor. From Fig. 23 it will be seen that the longer blades have two binding strips, while the shorter blades have only one. In some instances, although not in the *Tenyo Maru*, there are three such strips.

The over-all length of the turbine rotors, including the bearing, is in the case of the high-pressure turbine over 24 feet, and of the low-pressure and astern turbine over 33 feet. The turbine casings are of cast iron. The bottom portions of the steam and exhaust ends are cast in one, with bearing stools. The governing gear, fitted to each of the turbines, is so arranged that any increase beyond the required revolutions in any of the turbines shuts off the steam supply from the turbines until the revolutions fall to the normal speed. An emergency governor is provided to entirely stop the turbines should any serious increase in the revolutions take place.

The gland for the shaft passing through the end of the turbine is rendered steamtight by Parsons' latest improved method.

Boilers.—There are thirteen single-ended boilers, arranged in two separate boiler rooms, as shown in Figs. 7 and 8 on Plate No. XXIX. They are designed to work under Howden's system of forced draft, and are also arranged to burn oil fuel. There are four large fans, two in each boiler room, each driven by an independent engine. They were supplied by Messrs. J. Howden & Co. The oil-burning arrangements are of Lassoes' low-pressure system, and there are four special blowers of Green's vertical pattern, each driven by an independent steam engine for atomizing oil fuels. These four blowers take hot air from the hot-air duct of Howden's system through a common trunk, and discharge into a common pipe, by which means the hot air under a pressure is distributed to the oil burners. The furnaces are of the Morison type. The funnels are two in number, elliptical in shape, and rise 120 feet high above the furnace bars.

The Condensers and Pumps.—There are two main condensers, two independent twin air pumps and two Parsons' augmentor condensers. Each main condenser deals with each low-pressure turbine. The air pumps are of Weir's high-vacuum system and merchant-service design, having cast-iron tops and bases with gun-metal barrels, gun-metal buckets, bronze rods and special valves. The two sets of centrifugal circulating pumps are of the Mitsu-Bishi make, each having suction and discharge branches, and driven by open engines. There are two surface feed heaters. The shells of the heaters are of mild steel, and tubes and tube plates of brass. The main feed pumps are supplied by Messrs. Weir, and consist of two pairs of double-acting pumps. Each pair is capable of supplying the boilers when the turbines are working at their full power. The pumps work at ten strokes per minute, and are so connected that either pump may serve any boiler. These pumps have complete gun-metal water ends, gun-metal buckets, manganese-bronze rods, steel piston rods, and bronze valves in gun-metal seats. Two Weir direct-acting oil-circulating pumps have also been furnished, their duty being to circulate oil through the

turbine bearing, a constant and important duty, necessitating pumps of great reliability: one is for ordinary working, the other is a stand-by. There is also one Weir pump for water circulation of oil-cooling tank. Two Weir patent evaporators, of merchant-service pattern, are fitted, and are each capable of producing 50 tons of fresh water per day. A separate surface condensing plant, consisting of a condenser of Morison's "Contraflo" type circulating pump, Morrison's patent grease extractor is also provided for the auxiliary machinery for use in the port.

The Trials.—The trials of the *Tenyo Maru*, which occupied nearly three weeks, involved seven series of trips; the first three—the preliminary and progressive trials—were run on February 10, 13 and 15, 1908; the official trial on February 19, 1908, and the last three—the coal-consumption trials—on February 22, 25 and 27, 1908. The performance of the ship was exceptionally favorable from beginning to end. The steaming tests naturally excited considerable attention among marine constructors, and were each attended by representatives of several important interests.

The official trial consisted of six runs at full speed over the measured 3.458-knot Government course. The full speed guaranteed by the contract was 19 knots, but on this trial 20.62 knots was obtained. The results of the six runs are given on the following table:

Speed, in Knots, on Measured-Course Trials.

1st run, - -	20.50					
		20.49				
2d run, - -	20.48		20.56			
		20.63		20.59		
3d run, - -	20.78		20.61		20.61	
		20.59		20.62		20.62
4th run, - -	20.39		20.62		20.62	
		20.65		20.61		
5th run, - -	20.91		20.60			
		20.55				
6th run, - -	20.18					

On several occasions ahead and astern trials were made, and it was found that the time occupied to bring the vessel to a dead stop by putting the machinery from full ahead to full astern was 3 minutes 30 seconds, and to full ahead from full astern 3 minutes 30½ seconds. The satisfactory results of the *Tenyo Maru's* trials were not only of great importance from the point of view of turbine engineering, but must have been most pleasing to the Mitsu-Bishi Dockyard and Engine Works, who also attained equal success with the *Chiyo Maru* for the same service.

In conclusion, it may be added that the Mitsu-Bishi Dockyard and Engine Works have been lately provided with an experimental tank, fitted with apparatus and machinery of a most improved design, supplied by the well-known firm of Messrs. Kelso & Son, of Glasgow; and doubtless some modifications or improvement will be made on the third ship from the experimental data obtained in the tank. We hope to publish a description of this marine laboratory on some future occasion.—"Engineering."

S. S. President de Leeuw.—We recently announced that the Soc. An. de Remorquage à Hélice, of Antwerp, had decided to build another powerful sea-going tug and salvage boat combined, and had entrusted the order to the Kattendyk Works (Soc. Anon.) of that port.

In her official trial run on the Scheldt the result was most satisfactory, the engines working without a hitch, developing over 1,000 horsepower on a moderate consumption, and the ship in ordinary working condition making over 13 knots.

Mr. G. F. Amor, M. I. N. A. (directeur of the Kattendyk Works, Soc. An.), has favored us with the few following details of the vessel and her machinery: Length between perpendiculars, 124 feet; breadth, 24 feet; depth, 14 feet.

Flush deck, with bridge deck, on which is placed the steering house, and chart room beneath, with powerful steam steering gear. Under this deck are built side houses for salvage gear, stores, lavatories and large galley. The towing apparatus is exceptionally strong and convenient to manipu-

late. Steam windlass and stockless anchors and steam cap' stan, breakwater forward; crew are berthed aft, and forward there is a small but handsome saloon for passengers or others who may require to remain on board on salvage operations. There are two masts with fore-and-aft canvas, and one double funnel. The accommodation is steam heated. The ship is built entirely of Siemen's-Martin steel to Germanischer Lloyd highest class, the scantlings being 10 per cent. over their requirements. There are five watertight bulkheads and five water-ballast tanks, side and cross bunkers with a capacity of thirty days' steaming, and, in view of the important business which the owners have in towing in the Baltic, special provision has been made against the ice by additional framing and specially-designed stem, etc.

The ship has fine lines and a high degree of stability, having deep bilge keels as well as bar-keel rudder of single-plate type with flange coupling.

The engine is triple-expansion, surface-condensing, cylinders of $16\frac{3}{8}$, $26\frac{3}{4}$ and $44\frac{7}{8}$ inches, and stroke $29\frac{1}{2}$ inches, steam being supplied by two single-ended boilers 11 feet 2 inches by 9 feet 10 inches, of 185 pounds pressure. The H.P. cylinder is fitted with a piston valve and the I.M. and L.P. with balanced slide valves. The tunnel shafting is arranged in lengths suitable for removal and the propeller (designed and cast by Zeise, of Hamburg) can be removed and replaced without drawing the tail-end shaft. The Cedervall tube and Aspinall's governor have been fitted, and in the engine room are also fitted Caird & Rayner's evaporator, feed heater and filter. Special attention has been paid to the pumping plant, naturally, in view of the salvage services the vessel is designed to render. A 10-inch Gwynne centrifugal pump and 8-inch and 6-inch duplex pumps, by A. G. Mumford, have been fitted, together with a very complete installation of valve boxes for the suction and delivery hoses.

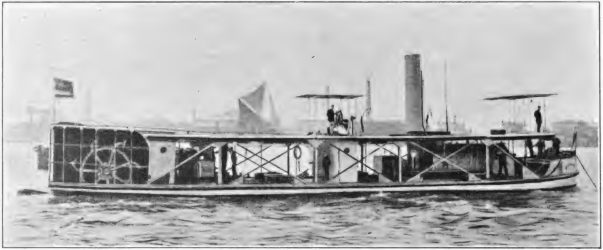
Such a powerful and complete vessel should prove of the greatest utility to the mercantile marine in Antwerp particularly, and the north of Europe generally, and we congratu-

late builders and owners alike in producing and owning such an exceptionally installed and serviceable boat. The fittings and accommodation of this tug are exceptionally fine, and the owners and those who have seen the vessel have expressed their pleasure at the handsome appearance of the saloon and interior.

It is interesting to note that one of the first commissions of the *President de Leeuw* was to tow the Royal yacht *Osborne* from Portsmouth to London. She previously performed a very quick tow down Channel, returning to Flushing at about 13 knots per hour.—"The Steamship."

We illustrate a Shallow-Draught Steamer recently built by Messrs. G. Rennie & Co., at their Greenwich yard, to the order of the Crown Agents for the Colonies, solely for towing purposes in shallow rivers of Northern Nigeria. The view shows the steamer as she appeared on the Thames; the following are her general dimensions: Length, 100 feet; breadth, 19 feet 6 inches; depth, 5 feet 6 inches; draught, loaded, with 10 tons of coal and stores, 3 feet 3 inches.

The hull is divided by transverse and longitudinal bulkheads, and is strongly stiffened with a system of tie rods, hogging girders and king posts of exceptional strength. Owing to the care which has been taken in stiffening the vessel a total absence of vibration was experienced during the trials, even at full speed. Accommodation for the crew is provided forward, the steering wheel is placed amidships, the pilot house being forward. By this means the steersman has complete control over the vessel. In steaming amongst the river traffic no difficulty was experienced in maneuvering. The vessel is propelled by stern wheels of the divided type, with feathering floats, the engines, of the compound non-condensing pattern, being situated in the center of the vessel. The boiler is of the locomotive marine type, the exhaust steam entering the funnel. As above stated, the vessel has been constructed solely for the purpose of towing, and great interest was experienced on the trial as to the way she would be able to handle and tow the ordinary Thames barge alongside; the results compared very favorably



SHALLOW-DRAUGHT STEAMER FOR NORTHERN NIGERIA.

with screw tugs drawing far more water. The speed of the vessel when running light was 9½ knots, which, considering her length and the fact that a high speed when running alone was not aimed at in the design, is most satisfactory. The guaranteed horsepower of the vessel—namely, 400—was exceeded by 7 per cent. Messrs. Plenty, of Newbury, were the sub-contractors for the machinery. Both the hull and machinery have been built under the superintendence of Messrs. Ridsdale, Wells & Kemp.

Laurentic.—Special interest attaches to the triple-screw Dominion liner *Laurentic*, from Messrs. Harland & Wolff's yard at Belfast, on account of the adoption in this vessel of a combination of reciprocating engines with a low-pressure turbine, the *Laurentic* being the first passenger steamer designed with this arrangement of machinery. Moreover, it has been generally assumed that the adoption of this novelty in the *Laurentic* is some indication of the owners' intentions with regard to the machinery of the other large liners which they are contemplating. This arrangement of machinery constitutes the vessel a triple-screw steamer, each of the wing propellers being driven by four-crank triple-balanced engines, and the central propeller by a turbine.

The object is, of course, to retain the advantages of the highly-perfected balanced reciprocating engines and at the same time get the benefit of the further expansion of steam in a low-pressure turbine, while avoiding the necessity for an astern turbine, which is essential in steamers fitted with turbines only. In this vessel, both for going astern and maneuvering in and out of port, the reciprocating engines will be more than sufficient, as they will develop over three-fourths of the total combined horsepower.

The *Laurentic* will be the largest vessel in the Canadian trade, being 565 feet long by 67 feet 4 inches beam, and 14,500 tons gross. She is designed to carry a large quantity of cargo, also a full complement of passengers—about 230 first-class, 430 second-class and over 1,000 third-class. As, of course, is well known, the double bottom, in addition to being an element of

strength and security, provides space for water ballast, which is also carried in the fore and after peaks. There are six cargo holds, and the bunkers are specially arranged to facilitate the coaling. The whole of the passenger accommodation has been arranged on generous lines. The *Laurentic* will signalize the entry of the White Star Line into the Canadian trade.—"Engineer."

Post Office Boat for Uruguay.—An interesting little vessel, 90 feet long by 14 feet beam, named the *Correo del Uruguay*, has just completed her trials on the Clyde, and will shortly be shipped to Montevideo. She has been built to the order of the Uruguayan Government by Messrs. Yarrow & Co., Ltd., Glasgow (formerly of Poplar, London), and is intended for loading and unloading mails from the steamers that call at the port of Montevideo. She is built of galvanized steel, and provided with one set of triple-expansion surface-condensing engines and a Yarrow water-tube boiler. There is a deck house aft containing the saloon and sleeping accommodation for three officials, and also a sorting room for mails. In the forward cabin there is accommodation for four assistants, and below deck there is sleeping space for the crew. There are two holds for carrying the mails, the forward hold being intended for heavy packages, in connection with which a derrick is fitted on the mast; the after hold is intended for the lighter mails. A complete electrical installation is provided for lighting the internal parts of the vessel, and a small searchlight is fitted on the top of the forward cabin. A stout hard-wood rubbing piece is worked all round the hull to serve as a fender in going alongside the mail steamers out in the roads. This little vessel is also provided with a 37-mm. Armstrong quick-firing gun forward. The official trial was made at the mouth of the Clyde in the presence of the Uruguayan authorities and the representatives of Lloyds, when a mean speed was obtained of 11.4 knots at 120 pounds steam pressure, and 13.3 knots at 220 pounds. The *Correo del Uruguay* will be shipped whole to Montevideo on the deck of a cargo steamer.

ASSOCIATION NOTES.

At a regular meeting of the Society, held on October 6, 1908, the following officers were nominated for election as President and Members of the Council for the year 1909:

For President:

Rear Admiral JOHN K. BARTON, U. S. N.
Captain F. H. ELDRIDGE, U. S. N.

For Secretary-Treasurer:

Lieutenant H. C. DINGER, U. S. N.
Lieutenant J. B. GILMER, U. S. N.

For Members of Council:

Commander H. P. NORTON, U. S. N.
Commander F. C. BOWERS, U. S. N.
Commander GUSTAV KAEMMERLING, U. S. N.
Engineer-in-Chief CHAS. A. MCALLISTER, U. S. R. C. S.
Commander W. W. WHITE, U. S. N., Retired.
Commander W. STROTHER SMITH, U. S. N.
Commander C. W. DYSON, U. S. N.

At a special meeting of the Society, held on October 29, 1908, the resignation of Commander Theodore C. Fenton, U. S. Navy, as Secretary-Treasurer was accepted, and Lieutenant H. C. Dinger, U. S. Navy, was appointed as Secretary-Treasurer for the completion of the year 1908.

MEETING OF THE A. S. M. E.

The next monthly meeting of The American Society of Mechanical Engineers will be held in the Engineering Societies' Building on Tuesday evening, January 12. The paper will be by Carl G. Barth, of Philadelphia, upon The Trans-

mission of Power by Leather Belting, illustrated by lantern slides. It will be a comprehensive summing up of the theory and practice of belting in which conclusions are drawn from the work of Lewis, Bancroft, Bird and others, who have made experiments upon the transmission of power by belting. Valuable charts have been prepared by the author for the solution of belting problems.

Mr. Barth's long experience in the scientific running of machine tools in connection with the introduction of improved shop methods, has shown the need of definite data for the application of belting to machinery and led to the development of the results contained in his paper. His data have been applied to belting in different plants for many years, giving an unusual opportunity to study the problem in great detail.

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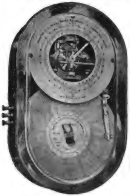

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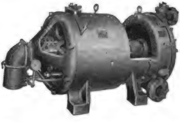

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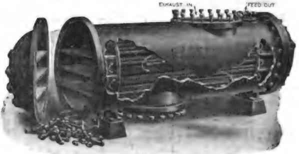

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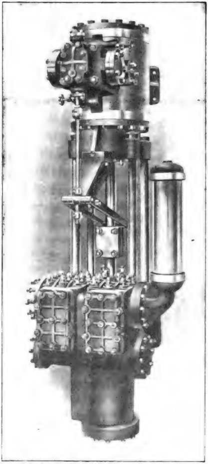
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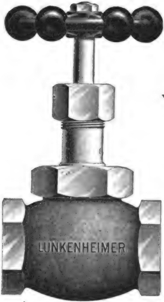

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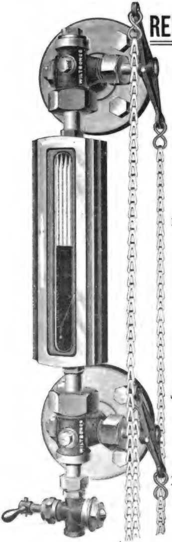

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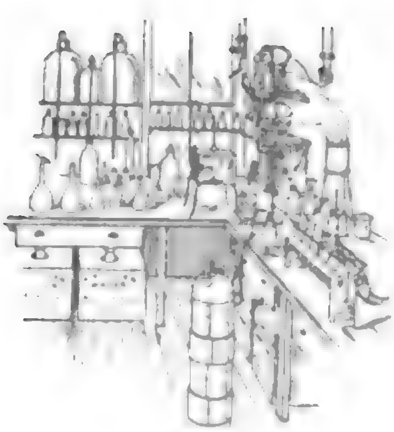

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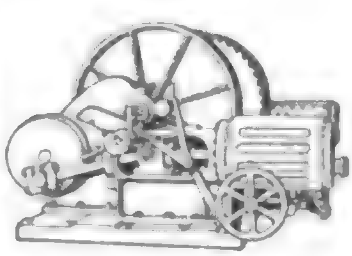

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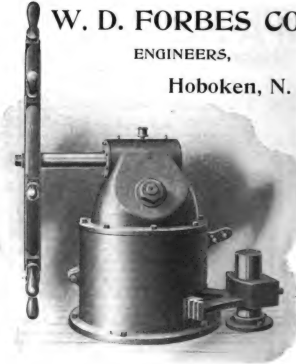

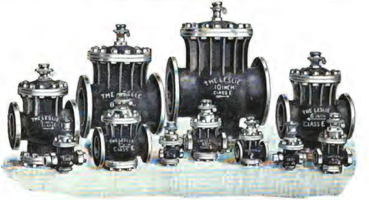

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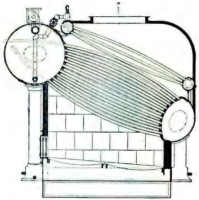

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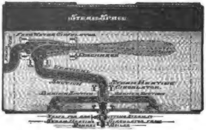
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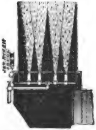

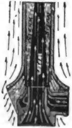

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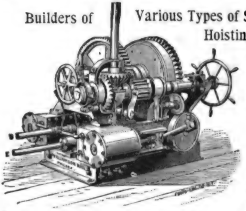

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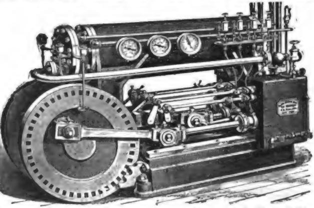

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S. S. *Mongolia*,	Pacific Mail S. S. Co.,	10,000	6
S. S. *Manchuria*,	Pacific Mail S. S. Co.,	10,000	6
S. S. *Massachusetts*,	Atlantic Transport Co.,	5,000	4
S. S. *Mississippi*,	Atlantic Transport Co.,	5,000	4
S. S. *Ligonier*,	Guffey Petroleum Co.,	2,500	2
S. S. *Larimer*,	Guffey Petroleum Co.,	2,500	2
U. S. Cruiser *Washington*,	U. S. Navy,	28,000	14
U. S. Battleship *Kansas*,	U. S. Navy,	20,000	14
U. S. Battleship *New Hampshire*,	U. S. Navy (building),	20,000	14
S. S. *Ontario*,	Merchants & Miners' Co.,	3,500	5
Dredge *Geo. W. Catt*,	Atlantic, Gulf & Pacific Co.,	1,000	2
Dredge *Ontario*,	Empire Engineering Co.,	1,000	1
Dredge *Oneida*,	Empire Engineering Co.,	1,000	1
S. S. *President*,	Pacific Coast S. S. Co.,	5,000	4
S. S. *Governor*,	Pacific Coast S. S. Co.,	5,000	6
S. S. *Columbia*,	York River Bay Line,	3,600	4
Four Engines for N. Odero Co., Genova, Italy, 4,000 I.H.P. each, for International Navigazione Italiana S. S. Co.,			16
Total cylinders in use up to October 1, 1906,			115
New Mallory Line Steamship, building at Newport News Shipbuilding & Dry Dock Co.,		8,000	2
New Texas Oil Co. Steamship, building at Newport News Shipbuilding & Dry Dock Co.,		2,500	4
New Gulf Refining Co. Steamship, building at the New York Shipbuilding Co., Camden, N. J.,		3,600	4
Two new Passenger Ships being built by the Kawasaki Dockyard Co., each 5,000 I.H.P.,			8
U. S. Battleship *Michigan*, U. S. Navy, building at the New York Shipbuilding Co., Camden, N. J.,		20,000	14
S. S. *Britannia*, Detroit B. I. & W. F. Co.,		2,000	1
S. S. *Favorite*, Great Lakes Towing Co.,		2,200	1
New Steamship (building), W. H. Becker, Cleveland, O.,		2,000	1
Two new Steamers (building), Wyandotte Trans. Co.,		1,000	1
One Steamship (building in England), for the Japanese Trade,			2

The Steamship *Texan* has run over 200,000 miles, and up to the present time there has been no necessity whatever of lining up any of the valve gear. Think of this for a record.

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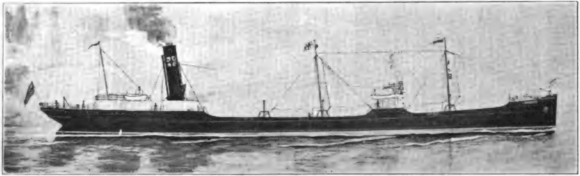

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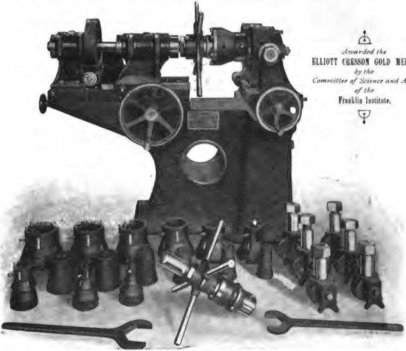

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